CENTER for AEROSPACE DOCTRINE, RESEARCH and EDUCATION

PRICE COMPETITION IN WEAPONS PRODUCTION: A FRAMEWORK TO ANALYZE ITS COST-EFFECTIVENESS

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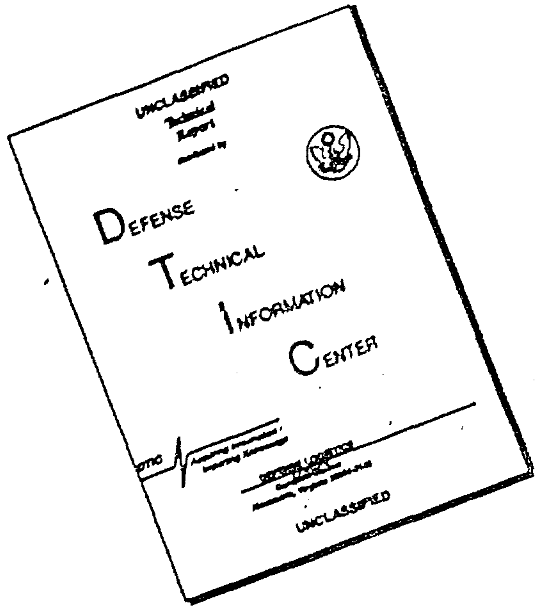

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Airpower Research Institute

Research Report No. AU-ARI-84-6

PRICE COMPETITION IN WEAPONS PRODUCTION: A FRAMEWORK TO ANALYZE ITS COST-EFFECTIVENESS

by

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Air University Press
Maxwell Air Force Base, Alabama 36112-5532

June 1984

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FOREWORD

The staggering costs of modern weapon systems have spurred the search for more economical methods of weapon procurement. Many defense establishment critics have touted increased reliance on competitive bidding and dual-source production as methods to reduce costs. Lieutenant Colonel Hampton's study addresses this important subject.

~~Colonel Hampton~~ proposes a discounted cash flow investment model as the appropriate framework for analyzing the cost-effectiveness of developing a second source during the production phase of a major weapon system acquisition. He outlines the factors and impacts that must be considered in second-source analysis and reviews six DOD program-specific analyses to determine if all factors and impacts were considered. Finally, he proposes a discounted cash flow investment model for second-source production analyses to help in deciding the probability that government investment in nonrecurring cost will be recovered.

We believe Colonel Hampton's findings are important in our continuing attempts to rationalize weapon systems procurement. Although everyone may not agree with his proposals, Colonel Hampton's study provides a significant challenge to those who have approached the subject in a less thorough and systematic manner.

Donald D. Stevens

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THE AUTHOR

Born in Peru and raised in Minnesota, Lt Col Richard Hampton graduated from the University of Minnesota in 1967 with an ROTC commission and a degree in business. His first two assignments were at McClellan AFB, California, and Eielson AFB, Alaska, as a procurement officer. In 1974 he completed his MBA at The George Washington University, specializing in the government contracting program. He was then assigned to Headquarters, Defense Logistics Agency as a procurement management staff officer. He taught economics and management at the Air Force Academy from 1977-80 and then attended the Air Command and Staff College. From ACSC he was assigned to the Hughes Aircraft Company, Los Angeles, administering government satellite contracts. He also served as a member of the source selection evaluation board for the MILSTAR communication satellite program. His doctorate is in government contracts and management from The George Washington University. He is currently assigned to the Air Staff and serves on the Defense Acquisition Regulation Council as the Air Force policy member.

PREFACE

My original charge from Brig Gen Dan Geran, AFSC DCS/Comptroller, was to develop for the cognoscenti an algorithm to use in analyzing the effect that the introduction of competition through second-sourcing would have on the cost profile of an acquisition of a weapon system if introduced into the production phase. It was my understanding that the algorithm would specify the parameters to be applied against program-specific data in a mechanistic fashion, cranking out the answer of whether it was cost-effective to develop a second source and subsequently budgeting for the competitive program. And General Geran had every right to expect me to develop the model. Several predictive models currently exist in the literature and he wanted to know which had the most validity.

I have not accomplished my original tasking! After reviewing the literature--which consisted of both predictive models and critiques of the models--I concluded that a mechanistic algorithm could not be developed. I concluded that there are simply too many variables that can affect the magnitude of savings or added cost on a given acquisition to formulate a mathematical model. And each critique that I reviewed drew the same conclusion!

The fact that an algorithm cannot be formulated does not make the need for a decision analysis disappear. Acquisition strategies must still be planned and budgets developed. In lieu of an algorithm, I am proposing that we view the development of a second source as an investment decision, made with the goal of obtaining a return on our investment.

My review of the literature revealed two widespread misunderstandings relating to competition--both in the legislative and executive branches. First was a confusion between the processes of formal advertising, negotiation, and competition. Many have equated formal advertising with competition, ignoring competitive negotiations as a means of competition. A second misperception exists that there is an empirically verified average savings that results when sole-source production programs are competed. Chapter 1 explores these misperceptions for the cognoscenti and layman alike because they are the foundation for many ill-conceived actions within both the legislative and executive branches.

Chapters 2 thru 5 are written for the cognoscenti, the acquisition professionals that must make the decision to second-source or not, and subsequently implement the decision. Chapter 2 outlines what factors and impacts must be considered in a second-source analysis. Chapter 3 reviews published studies of past competitive procurements. It determines the method and data used to arrive at study conclusions and provides a judgement of the validity of study conclusions. Chapter 4 reviews DOD program-specific analyses to determine if all factors and impacts delineated in chapter 2 were considered. Chapter 5 proposes a discounted cash flow investment model for use in competition analyses.

I have been particularly fortunate to have this tour as the Air Force Systems Command Research Fellow for 1983-84. It contributed to my professional education as an attendee at the Air War College. And my research project enabled me--through an in-depth review of several Army, Navy and Air Force programs, and my travels to all AFSC buying divisions--to gain a better understanding and appreciation for the complex interaction the program manager must orchestrate between the contractor, engineers, program control, comptroller, and contracting personnel among others.

The review of studies and critiques--all of which were either accomplished in-house or funded under government contract--revealed a disconnect between researchers and practitioners as the critiques of published predictive models raised the flag of caution on the use of various studies. Yet the use of study results in program-specific analyses show how quickly the key assumptions and cautions of study conclusions fall by the wayside, and the critiques ignored, as practitioners inappropriately applied study conclusions by grabbing any "authoritative" source to accomplish their analyses.

It also seems that the Department of Defense can be its own worst enemy. We provide data, either knowingly or naively, about savings estimates that are not accurate. And we do not take action to correct existing misperceptions. OMB and the Congress then take actions based on the inappropriate information. We must somehow stop this vicious cycle.

I want to thank the many people who assisted in making this study possible. Brig Gens Dan Geran, AFSC DCS/Comptroller, and James Denver, AFSC DCS/Contracting and Manufacturing, whose insight foresaw the need for the study. Cols "Steve" Stevenson and Dennis Madl, HQ AFSC/AC; Tony Deluca, HQ AFSC/PM; and those program control, comptroller, and contracting personnel at all AFSC buying divisions that gave so unselfishly of their limited time. And I owe a special debt of gratitude to Lt Col Jim Streets, Associate Professor of Economics at the Air Force Academy, for his patience in helping me understand the detailed world of econometrics. While each contributed to my understanding of the subject matter, the study conclusions are my own and I must necessarily take responsibility for them.

The excellent facilities and people of the Air University and specifically the Airpower Research Institute in no small fashion contributed to this study. Dr Dave MacIsaac served as a senior advisor; Hugh Richardson suffered through the editing process with me; and Dot McCluskie, Marcia Williams, Annie Dinkins, Marshall Fulmer, and Elaine Dillon did a superb job of typing the multiple drafts of the study and preparing its graphics. And to A1C Don Wilborn, who prepared numerous travel orders, arranged for transportation, and handled many administrative details, I also owe a thank you.

Finally, I am indebted to my wife Judy. The love, support, and cooperation she gave me this year--through the travel and writing--made it easy to dedicate my time to this important effort. She even understood those Saturdays when I deferred attendance at Auburn University football games to work on the research--although I am not too sure it was with as great a level of understanding as it was with the rest of the year!

RICHARD J. HAMPTON
Lieutenant Colonel, USAF
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CHAPTER 1

INTRODUCTION TO SECOND-SOURCING

Capitalism has given the United States the highest standard of living ever achieved by any society in the world. The basic tenets of capitalism include private ownership of the factors of production, with prices, production and the distribution of goods being determined by competition between enterprises in a free-market system. These tenets stimulate technological innovation and drive prices down as more entrepreneurs enter the marketplace in anticipation of earning a profit, a return on their investment in the factors of production, and a reward for their risk taking. Yet, in fiscal year (FY) 1982, 58.9 percent of Department of Defense (DOD) procurement dollars and 65.8 percent of Air Force procurement dollars were expended noncompetitively. And of the total FY 1982 procurement dollars expended, 25.6 percent of DOD dollars and 48.6 percent of Air Force dollars were noncompetitive follow-on production contracts. Because of these apparently high percentages and the high costs of today's weapons systems both in absolute cost and the overruns that are incurred, the executive and legislative branches are applying pressure to increase competition in the production phase of the weapons acquisition process with the hope of reducing system costs and improving system technical performance.

Research Questions

This study explores dual-sourcing as a means of increasing production competition and provides an analytical framework for assistance in making dual-sourcing decisions and budgeting for weapon systems that will be dual-sourced. Dual-sourcing during production exists when two or more firms are capable of furnishing government requirements with contract award determined by price, either through split-awards over time or a competitive buy-out.

To accomplish this objective, the primary research question guiding the study was:

What analytical framework is appropriate for estimating, a priori, the costs and benefits of dual-sourcing weapons in production?

In answering the primary research question, three subsidiary research questions had to be answered:

What factors must be considered when measuring dual-source savings by quantifying its costs and benefits?

What ex post (after the fact) academic and consultant studies have been accomplished quantifying the costs and benefits of dual-sourcing, and what predictive methods have they developed for ex ante (before the fact) use?

How have military system program offices and comptrollers estimated ex ante the costs and benefits of dual-sourcing?

Chapter 2 addresses the first subsidiary research question and identifies cost and benefit factors that must be quantified to estimate the net cost impact associated with dual-sourcing. Chapter 3 reviews and critiques previous studies by both the academic and consultant communities which attempt to quantify the savings on weapons systems that have been dual-sourced, thereby answering the second subsidiary question. Chapter 4 treats the third subsidiary question and reviews internal government studies relating to the dual-sourcing decisions for a sample of programs. Chapter 5 discusses a proposed analytical framework for making initial dual-sourcing decisions and subsequent dual-sourcing budgeting decisions. Chapter 5 also discusses how the framework should be used in DOD decision-making and the implications of the findings for acquisition management personnel. First, however, the balance of this chapter differentiates competition from other acquisition concepts, reviews the stages of the acquisition process, discusses recent pressures to increase production competition, and briefly surveys the competition literature. It also identifies the reasons why a high percentage of Air Force procurement dollars are spent noncompetitively and sets forth the circumstances under which costs can be avoided by dual-sourcing weapon systems.

Competition and Formal Advertising

Maintaining competition in the acquisition process by retaining two or more viable producers as long as is economically beneficial is the goal of Department of Defense procurements[1]; formally advertised procurement is the preferred method to maintain competition.[2] Here it is useful to draw a distinction between formal advertising and competition because sometimes there is confusion in the usage of the terms.

Formal advertising and negotiation are two concepts grounded in public law. Formal advertising is a procedure whereby the government develops detailed specifications for a requirement, publicly issues an invitation for bid (IFB), provides adequate time for bids to be submitted, and specifies an exact time and place at which the bids will be publicly opened. Bids are evaluated as to compliance with the strict instructions of the IFB and the contract is awarded to the lowest responsive responsible bidder. This is in contrast to the concept of negotiation, which is defined in law as any method other than formal advertising. Negotiation is more flexible than formal advertising since ongoing discussions regarding the project's technical and cost parameters can take place prior to contract award.[3]

Competition can exist using either the formal advertising or negotiated procedures. Figure 1-1 illustrates the percentage of dollar awards to competitive and noncompetitive procurements. Competitive procurements include both formally advertised and competitively

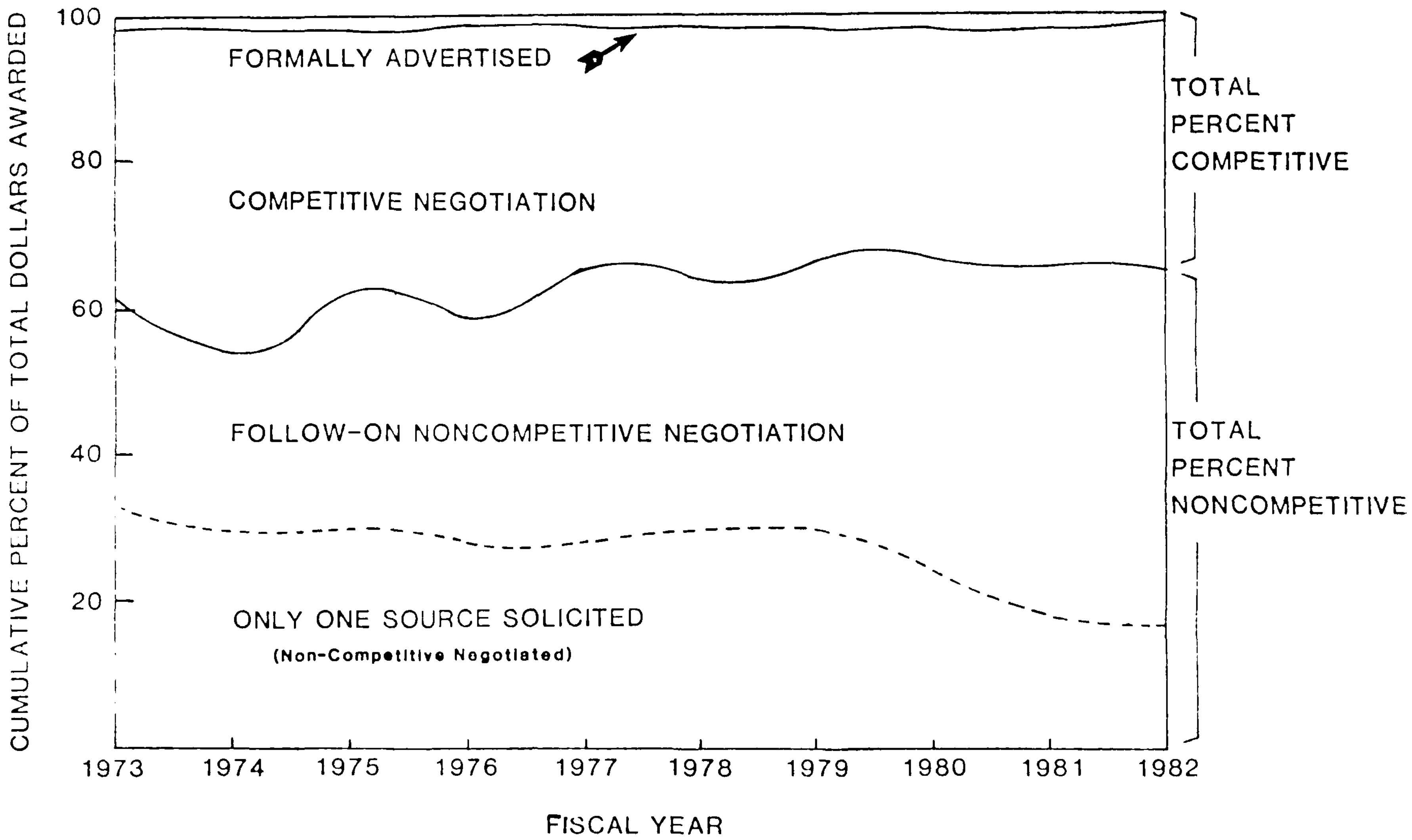


Figure 1-1. Competitive Trends in USAF Contracting

negotiated contracts and account for 34.3 percent of dollar awards. Noncompetitive awards are those where only one source is solicited or the award is made noncompetitively as a follow-on to either technical or design competition.

Semantic confusion often results in the error of equating competition with only formally advertised actions. For example, a 1978 Rand study quotes Senator William Proxmire: "Of all [DOD] procurement, only 11 percent is competitive."[4] What the senator reported was only the formally advertised percentage of procurement dollars. And in 1983 Senator David Pryor stated "It is nothing short of shocking to hear that competition at the Pentagon is limited to only 6 percent of total defense contract dollars."[5] Again, as can be seen from figure 1-1, he also has equated competition with formal advertising.

Weapons Acquisition Process and Competition

Four separate stages characterize the weapons acquisition process: concept exploration, demonstration and validation, full-scale engineering development, and production and deployment of the system. One must have an understanding of this process and how competition is generated at each stage in order to (1) understand why there is a high percentage of noncompetitive contract awards, and (2) why there are increasing pressures to develop competition in systems procurements.[6]

The first three stages--concept exploration, demonstration and validation, and full-scale engineering development (FSED)--comprise the research and development (R & D) phase of the acquisition process. In the concept exploration stage, mission needs or requirements are identified and potential alternate systems design concepts to satisfy identified needs are evaluated. Performance and mission envelopes (capabilities) and operational concepts are committed to paper and sometimes prototype hardware is developed during the second (demonstration and validation) stage when the best technical approach is selected. This is followed by the FSED stage during which firm engineering drawings are drafted, production processes and procedures developed, and engineering data lists compiled. Finally, the production and deployment of a weapon system is accomplished from the detailed design data developed during the R & D stage.

Figure 1-2 nominally depicts the budget profile of a typical weapon system acquisition by process stage over its program life.[7] As each stage of the process is accomplished, technical and cost uncertainty is progressively reduced. This results from the establishment of the technical performance baseline of the system and a closer definition of design characteristics and production costs during each successive stage. For example, during the concept exploration stage, different systems concepts such as missiles and bombers vie for selection to accomplish a required mission. Alternate subsystems for a selected system are generally evaluated in the demonstration and validation stage. During full-scale engineering development, design changes can be made to the selected subsystems. And engineering changes are the only changes usually made in a system during the production stage.[8]

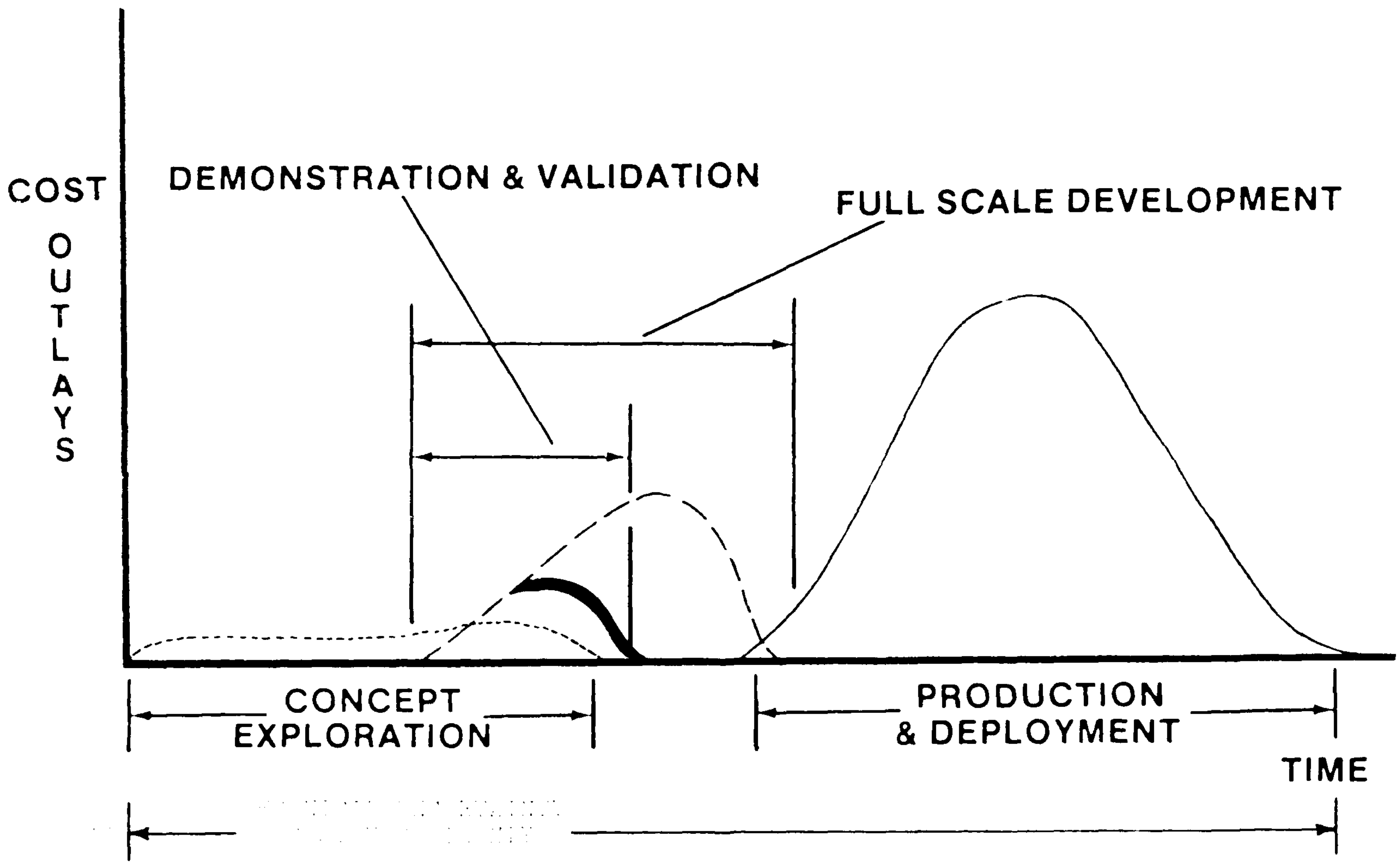


Figure 1-2. Acquisition Cost Distribution and Uncertainty

We will now briefly review the evolution of the contractor selection process as it relates to the acquisition process in order to identify factors that have led to a significant percentage of noncompetitive DOD contracts being awarded.[9]

Evolution of Sole-Source Procurements

Before the turn of the century, formal advertising was the most frequently used procurement method. In-house arsenals developed detailed specifications, which allowed private enterprise to bid firm prices against the detailed specification package.

Weapons gradually became increasingly complex and the system of in-house arsenals was partially dismantled after the turn of the twentieth century. Therefore, with no definitive specifications--for most aircraft procurements for example--the government negotiated contracts on a sole-source basis. In 1926, in an effort to stimulate both the technical development of aircraft and competition in their procurement, Congress passed the Aircraft Production Act.[10] This act authorized design competition in the procurement of aircraft and the purchase by the Air Corps of designs completed by competing contractors. The Air Corps in the 1930s went beyond the concept of design competition and began asking competing contractors to submit a full-scale flying prototype of their design. The prototype was requested to correct the problem of unproven technical ideas being submitted during paper design competition and subsequently developed aircraft being much different from submitted designs.

The technical complexity of systems continued to increase during the 1930s to the point where the costs of prototype development and the exigencies of World War II discouraged the development of prototypes. For example, Merton Peck and Frederic Scherer, writing at the Harvard University, estimate the prototypes in the early years of military aviation cost as little as $6,000 to $10,000. By 1939, however, this cost had risen to $600,000 and by the 1940s averaged several million dollars each.[11]

The costs of prototype development increased after World War II. For example, initial jet fighter prototypes in the 1950s cost $10 to 20 million, a cost that the Air Force felt was too much to spend on prototyping. Consequently, the emphasis shifted from prototype competition back to design competition.

Technology continued to develop at an increasingly faster pace after the Korean War, as did the perceived military threat to the nation. The United States capitalized on state-of-the-art high technology to counter the threat. Feasibility studies of the basic underlying scientific concepts preceded the design of the system. Management competition was the answer to these new technological developments as the cost of parallel systems design became increasingly expensive.[12] Under management competition, the contractor submits the

general technical and organizational approach he will use in exploring the feasibility of a given technology. The best submission during the competition is chosen as the development contractor.

Coupled with the galloping technical advance which occurred during this period, the launching of Sputnik by the Russians in 1957 created a sense of urgency to decrease the developmental time associated with major weapon systems. One congressional report referred to this event by saying:

> If the Pearl Harbor attack unified this nation and mobilized its people for World War II, Sputnik was an electrifying event of similar impact for a cold war decade of missile and space development. It served to mobilize US science and technology through the creation of new agencies and offices, subsidies to higher education, space ventures which led finally to a triumphant landing on the moon, and defense efforts which greatly expanded strategic forces for deterrence against nuclear war.[13]

Procurements during this period generated the large cost overruns of the 1960s and led to a general concern by the Congress regarding the acquisition process. Dr. John Foster, Director of Defense Research and Engineering, in testifying before the Congress, stated how the existing national situation and a concern for weapon system development time created the problems of the 1960s.

> Certainly we came out of the fifties with a practice that in fact arose from the national situation. You will recall we were faced with an alleged "missile gap." We thought we had a strategic problem on our hands and were forced to develop weapon systems that had not been thoroughly engineered and risks removed. These were not representative of the state of the art. The art had to be put together and produced. There was at that time, a great deal of development-production concurrency. It was based on a felt need, and policies had to be flexible enough to meet that kind of practice.[14]

This concern for lead time resulted in several acquisition system changes. Time schedules were compressed through the use of concurrency. Production overlapped development and deployment overlapped both development and production. "Crash programs were instituted. Special offices were created with authority to command the needed resources for system development and to communicate quickly through streamlined channels with higher echelons."[15]

Peck and Scherer, in their definitive study referred to earlier, found that during this period of the "missile race," the actual costs of

weapons systems varied from original estimates by a factor of 3.2; developmental time was 1.36 times longer than forecast; and the performance levels of developed systems ranged from .8 to 2 times projected levels.[16] They attributed these results to technological advances which created uncertainty at the outset of the program, the sense of urgency which existed during the missile race, and the concomitant lack of regard for program cost.

In 1961 Robert S. McNamara became secretary of defense. The perceived "missile gap" was found nonexistent, and he attempted to place as much importance on cost as the time factor in the acquisition of weapon systems. One of his innovations was total package procurement (TPP), a contracting method in which the contractor agreed to develop a weapon system which met required performance specifications at a given cost. According to McNamara, TPP would broaden competition and reduce the use of cost-plus fixed-fee-contracts.[17] It also shifted major cost risks to the contractor for developing state-of-the-art technology.

The C-5 aircraft was the first major program to be procured using the total package procurement acquisition method. Contracts were written early in its infancy on a firm-fixed-price basis. However, because cost was locked in too early in the procurement process, Lockheed almost went bankrupt and the structural integrity of the C-5 wing is such that it is currently undergoing a major wing modification. Total package procurement as a concept died after this experience and the use of cost-type contracts again increased with technical competition being the primary selection criterion.

Types of Competition

This rather terse review of the evolution of the systems acquisition process reveals that as systems became more technically complex and expensive, the selection of system contractor was made on technical considerations early in the acquisition process to minimize the expenditure of time and development cost. Stated differently, program managers selected the winning contractor as early in the process as possible to minimize the costs of keeping two contractors involved through FSED.

These trade-offs between time and cost are substantial because the level of research, development, test, and evaluation (RDT&E) expenditures on a major program is high. For example, as shown in Table 1, Column 4, the estimated base-year RDT&E costs for the A-10 at source selection were budgeted at 281.9 million in FY 1970 dollars. The B-1B program baseline RDT&E costs were estimated at 2.58 billion in FY 1981 dollars. Competition strategy for the A-10 involved a prototype competition between the Northrup A-9 and Fairchild A-10 with the source selection being made at the beginning of FSED. If competition had been continued into FSED for the A-10 or the other programs, RDT&E costs would have been even higher. Other major weapon systems programs as

shown in Table 1-1 have used a similar strategy to select the sole-source contractor at initiation of FSED to minimize up-front development costs.

While competition was used to select the winning contractor in these programs, a distinction must be made between price and technical competition. As is shown in Column 7, RDT&E expenditures as a proportion of total acquisition costs range from a low of 5 percent for the F-16 to 39 percent for the E-3A aircraft in base-year dollars. And considering that total RDT&E expenditures include full-scale engineering development costs, source selection was made in the F-16 program with less than 5 percent of program expenditures made.[18] Examined another way, competitive price pressures for the production stage of the acquisition were removed based on technical competition with less than 5 percent of program expenditures incurred. Similar inferences can be made with data for other programs listed in the Table. And because of the technical and cost uncertainties remaining in the program, there is an inability to lock in contractually at the pre-FSED stage the benefits of competition for pricing of weapons in production.

Exploring the distinction between technical and price competition more closely, figure 1-3 relates types of competition with the stage of the acquisition process. Early in the process, paper, management, and prototype technical competition prevails. And because of the technical uncertainty, production costs cannot be estimated with any degree of confidence and contractors are unwilling to enter into fixed-price production contractual arrangements. Accordingly, the government uses cost-type contracts and bears the risk of cost uncertainty. As system characteristics and baselines became firmer, use of fixed-price contracts and price competition increases.

The Office of Federal Procurement Policy states that "competition can involve evaluation of new ideas, productivity improvements, new products and cost factors, as well as a firm's technical and management ability."[19] Paper, management and prototype competitions have already been discussed and it was shown that source selection using these methods was based on technical competition. A brief description of the types of price competition is given to illustrate their use to stimulate price competition, either singularly or in combination, during the production stage, while eliminating some of the duplicate up-front FSED costs.[20]

Technical Data Package (TDP)

The TDP is the technical description of an item adequate for use in procurement. This description defines the required design configuration and assures adequacy of item performance. It provides the baseline against which contractors can submit firm-fixed-price bids.

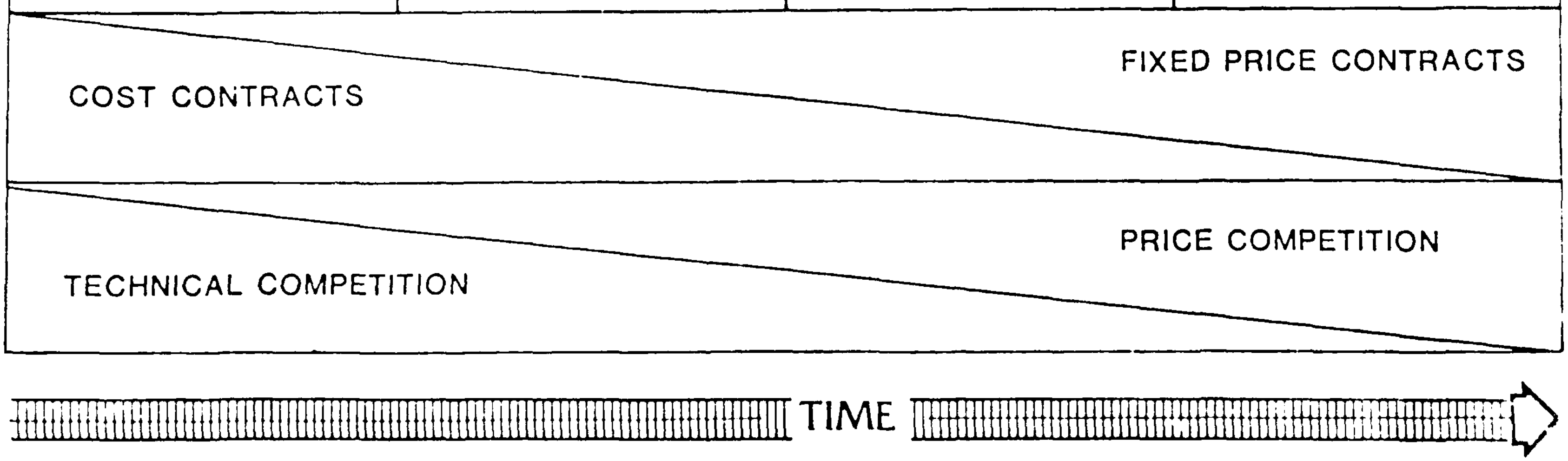
Table 1-1

BASE YEAR PROGRAM RDT&E EXPENDITURES AS A PERCENT OF
TOTAL BASE YEAR SYSTEM ACQUISITION COSTS
(DOLLARS IN MILLIONS)

Program	Base Year	Quantity	Budgeted RDT&E Col 4	Budgeted Procurement Col 5	Budgeted System Total Col 6 = 4 + 5	RDT&E as Percent of Total Col 7 = 4 ÷ 6
A-10	1970		281.9	1,486.5	2,489.7	.18
B-1B	1981	100	2,582.6	17,862.2	20,444.8	.12
F-16	1975	2,165	901.3	16,139.7	17,041	.05
E-3A	1970	43	1,259.8	1,906.6	3,166.4	.39
AMRAAM	1981	17,123	597.1	2,888.5	3,485.6	.17

Source: Selected Acquisition Reports.

CONCEPT EXPLORATION	DEMONSTRATION & VALIDATION	FULL SCALE DEVELOPMENT	PRODUCTION & DEPLOYMENT
-PAPER COMPETITION -MGMT COMPETITION	-PROTOTYPE -PAPER COMPETITION	-PARALLEL DEVELOPMENT -SUBSYSTEM -PRICE/TECHNICAL	-COMPONENT BREAKOUT -SECOND SOURCE * LEADER/FOLLOWER LICENSING TEAMING COPRODUCTION -PRICE TDP-FFF



* Split Award/ALL or None

Figure 1-3. Types of Competition and Contracts Related to Stages of the Weapons Systems Acquisition Process

Form, Fit, and Function (F^3)

The form, fit, and function (F^3) method is the description of military equipment by performance characteristics. The equipment is described in terms of output, function, and operation. External configuration, mounting provisions, or interface requirements may be included. But details of design, fabrication, and internal structure are normally left to the option of the contractor.

Leader/Follower (L/F)

The leader/follower (L/F) method is an acquisition technique under which the developer or sole source producer of an item or system (the leader company) furnishes manufacturing data, assistance, and know-how, or otherwise enables the follower company to become a source of supply for the item or system.

Educational Buy

An educational buy is a contract to provide a firm the opportunity to learn how to manufacture limited production quantities of a military item of equipment in accordance with a government TDP. Normally, the purpose of the method is to generate a competitive second source for an item which has previously been bought noncompetitively.

Directed Licensing

The directed licensing method is akin to leader/follower in that the leader provides data and assistance to help a follower become a qualified producer. However, with licensing not only is assistance provided but the developer (who may be the leader or subcontractor of the leader) is selling or renting something he owns (patents, trade secrets, etc.).

Contractor Team Arrangements

Contractor team arrangements involve a prime contractor arrangement where two or more companies form a partnership or joint venture to compete as a potential prime contractor using their combined knowledge and abilities.

Coproduction

Under this concept two or more prime contractors develop or produce different subsystems or major components of a weapon system. They then transfer learning to the other contractor and both compete against each other for contract awards.

Component Breakout

Component breakout is the process of dividing an end item into its component parts so that the components may be purchased directly from the manufacturer rather than from the end item prime contractor. The term "component' includes subsystems, assemblies, subassemblies, and repair parts.

Competition Savings

These methods can be used to stimulate price competition and possible cost avoidances during the production of weapons. An example should help the reader visualize how this is accomplished.

The budget profile in the typical program includes all nonrecurring costs such as development and tooling costs. It also includes recurring or variable production costs. A typical program total cost profile reflecting these costs over time is nominally shown in figure 1-4 and reflects early selection of the prime contractor based on technical

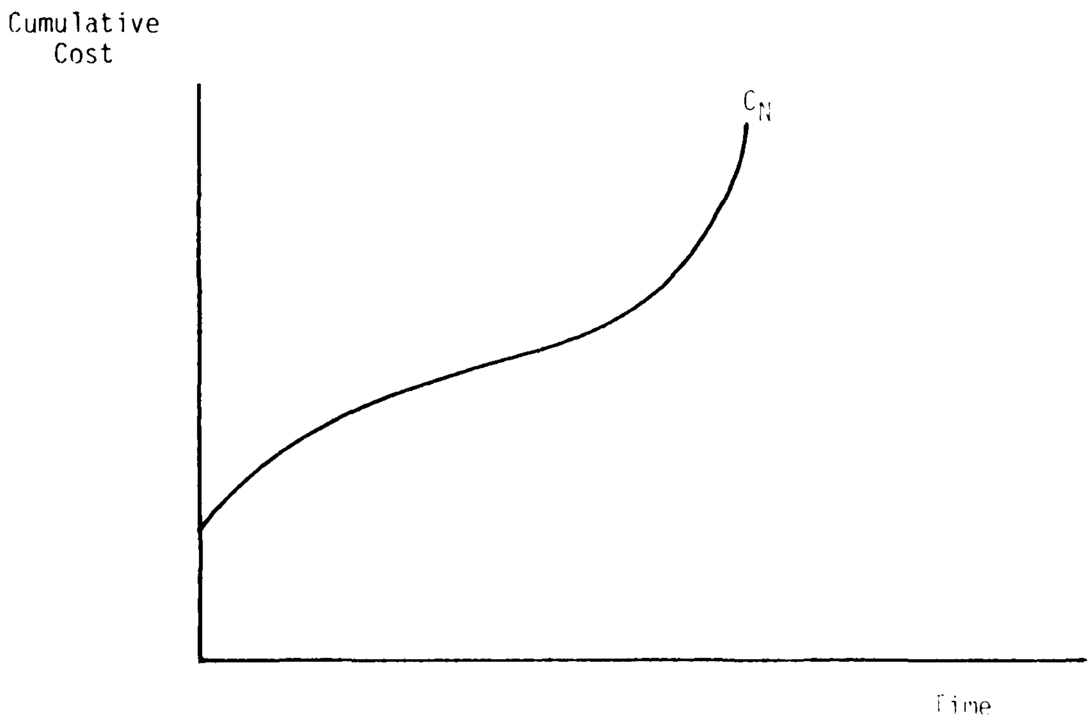


FIGURE 1-4. Cumulative Program Cost

competition with a sole-source production follow-on contract. This graph represents the algebraic summation of total program expenditures for a given program over time as reflected in figure 2.

Assuming that price competition in production is desired after the design of the system is accomplished by the sole-source contractor, a second source could be developed using one of the variety of strategies outlined earlier. This strategy requires a substantial up-front initial investment to enable the second source to produce the item. These investments are usually made with the anticipation that out-year recurring expenditures will be reduced enough to offset the additional investment in developing the second source. The situation can be depicted as shown in figure 1-5. C_n reflects the total cost profile for noncompetitive production procurement and C_c reflects the competitive total cost profile. C_c is initially above C_n which reflects the increased up-front funding required to develop the second source as shown by its intercept on the Y axis. C_c eventualy intersects C_n because the recurring costs in the competitive situation are less than in the sole source situation as reflected in the slopes of the total cost curves. The area between C_n and C_c where C_n lies above C_c reflects cost avoidances to the government. It is this area that previous studies have attempted to predict by quantifying the up-front investment and the reduced recurring program costs.

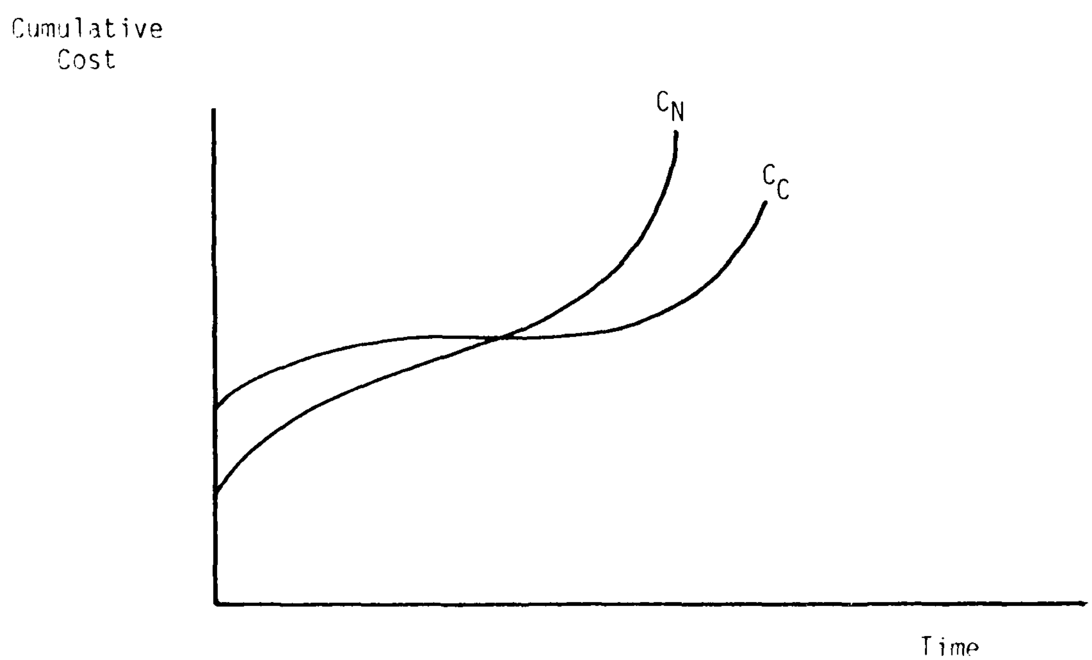


FIGURE 1-5. Cumulative Program Cost

Delimits

Several previous studies have attempted to quantify the costs and benefits derived from dual-sourcing by examining program data ex post to determine the impact of introducing competition into the production phase. This study is delimited to the dual-sourcing decision of weapons in production for three reasons: first, because of the high percentage of procurement dollars spent noncompetitively for the production of weapons; second, increased pressure to secure competition in production is developing, and third, many studies have been published which use different methodologies to arrive at different conclusions when analyzing the same dual-source procurements.

We have already alluded to the first of these reasons. The initial two stages of a weapons procurement in most cases involve technical competition as two or more contractors vie for selection of their technical concept by the government on the basis of its technical merit. In contrast to this process, which is coded as competitive negotiation, the majority of follow-on production contracts are awarded noncompetitively. Therefore, to increase competitive awards, more must be known about the largest noncompetitive award category and noncompetitive follow-on procurements.

Secondly, legislative and executive branch pressures are being applied to increase production competition. Finding 19 from the 1973 Project Ace study done by Air Force Systems Command stated "Second-sourcing to preserve competition and reduce cost is not being utilized in all appropriate instances."[21] More recently, on 2 March 1981, Deputy Secretary of Defense Frank Carlucci initiated his Acquisition Improvement Program by chartering five working groups to make recommendations on improving the acquisition process. On 31 March 1981 the working groups provided their recommendations to Carlucci, who published his 31 initiatives on 30 April 1981. On 27 July 1981, he added the 32nd initiative--competition--specifically referring in part to second sourcing.

The President issued Executive Order 12352 on 17 March 1982 directing agencies to develop criteria to enhance competition and limit noncompetitive actions. In response to the executive order, Secretary of Defense Casper W. Weinberger, in a 9 September 1982 memorandum stated:

> The Department of Defense components are to place maximum emphasis on competitive procurement. . . . All personnel involved in the acquisition process from the first identification of the requirement through the execution of the purchase should recognize this responsibility.[22]

President Reagan reaffirmed his emphasis to the heads of departments and agencies in an 11 August 1983 memorandum, which stated in part:

> Numerous examples of waste and exorbitant costs due to the lack of competition have been detailed by the Congress and the

> press during recent months. Although efforts have been initiated by this Administration through the Reform '88 Management Improvement Program to correct this long standing problem, I am convinced that more needs to be done.[23]

He directed that the Office of Federal Procurement Policy issue a policy restricting use of noncompetitive procurement practices.

The Congress has emphasized dual-sourcing in recent legislation. In its DOD appropriation legislation for FY 1984, the Congress directed that the Secretary of Defense submit to the Congress prior to the initiation of full-scale engineering development of any major weapons system, either:

(a) a certification that the system or subsystem being developed will be procured in quantities that are not sufficient to warrant development of two or more production sources, or

(b) a plan for the development of two or more sources for the production of the system or subsystem being developed.[24]

Additionally, legislation has been introduced into the Senate (S-1904) which would require the Defense Department to increase the amount of its contract dollars awarded by competitive formal advertising by 5 percent per year until 70 percent of all awards are competitively bid. The cumulative effect of these actions indicates the President and the Congress are serious about more production competition through dual-sourcing. Consequently, the Department of Defense must better understand how to budget for procurements that involve dual-sourcing.

The third reason this study is delimited to dual-sourced production procurements is that many existing studies outline various methodologies available to quantify the costs, benefits, and budget profiles of dual-sourced procurements. When these studies analyze the same dual-sourced procurements using different analytic methods, they develop different savings estimates. More important, however, is that none of these studies of several dual-sourced programs has identified a consistent set of cost and benefit relationships existing between programs. Some programs cost the government more as a result of dual-sourcing while others cost less. Something must be done to clear up this confusion.

Program managers and budget personnel must better understand the impact of dual-sourcing on their time-phased budget so they can balance the increased emphasis on production competition with the uncertainty of its results. This is particularly important in light of the fact that budgets for each weapon system are done by program on a one-year basis. If the estimates of the budget profile are wrong, overruns could occur that would lead to severe congressional and public criticism.

This chapter presented the research questions, and differentiated between the independent concepts of technical and price competition and how they are used in the different stages of the acquisition process.

It also identified technological and cost uncertainty and the high cost of developing weapons as the major reasons why sole-source awards account for a high percentage of the total dollar value of contract awards. Moreover, as was also seen, the executive and legislative branches are exerting pressures to increase price competition during follow-on procurements through use of one or more of the techniques described. Finally it identified the confusion of equating formal advertising with competition.

Chapter 2 will identify the costs and benefit factors that must be considered in a dual-sourcing decision.

NOTES

CHAPTER 1

1. Under Secretary of Defense (R&E) Memorandum, 28 February 1983 in Defense Acquisition Circular 76-43, 22 March 1983.

2. 10 U.S. C. 2303.

3. Among other reasons, negotiations are authorized in an emergency, for classified purchases, research and development, and education contracts among others. Exceptions are outlined at 10 U.S.C. 2304(a).

4. Michael D. Rich, Competition in the Acquisition of Major Weapon Systems: Legislative Perspectives, R, 2058-PR (Santa Monica, Calif.: The RAND Corporation, November 1976), 8.

5. Defense Daily, 3 October 1983, 147.

6. See DOD Instruction 5000.1, Major Systems Acquisition for a complete description of tnese concepts.

7. Adapted from Robert M. Seldon, Life Cycle Costing (Boulder: Westview Press, 1979) 10.

8. The evolution of each weapon system program is unique and might deviate from this stylized example. The purpose of the example is to show how technical and cost uncertainty are reduced over time.

9. For those interested, a more complete discussion of pre-1960 developments can be found in Merton J. Peck and Frederic M. Scherer, The Weapons Acqusition Process (Boston: Harvard University, 1962), 344-348, and US, Senate, Committee on Armed Services, Report on Procurement, 86th Cong., 2d Sess., (1960), 16-17.

10. 44 Stat,. 784, 787.

11. Peck and Scherer, Weapons Acquisition, 345-346. It has also been estimated that requirements definition alone for the B-1 bomber were over $250 million, many times the cost of prototype development in the 1930s. And according to Jacques Gansler, the total cost of industry proposed efforts on the F-111 was estimated to be $45 million. Jacques S. Gansler, The Defense Industry (Boston: The MIT Press, 1980), 296.

12. Fred Dietrich, "Systems Acquisition: How A-109 Can Help Shorten the Process," Office of Federal Procurement Policy Paper, undated, 1.

13. US, Congress, House, Committee on Government Operations, Policy Changes in Weapon System Procurement, H-Rpt 91-1719, 91st Cong., 2d Sess., 1970, 4.

14. Dr John S. Foster, Director of Defense Research and Engineering, quoted in US, Congress, House Committee on Government Operations, Policy Changes in Weapon System Procurement, Hearings before a subcommittee of the House Committee on Government Operations, 91st Cong., 2d Sess., 1970, 34.

15. Policy Changes, H Rpt 91-719, 5.

16. Peck and Scherer, Weapons Acquisition, 22-23.

17. Robert S. McNamara, The Essence of Security, Reflections in Office (New York: Harper & Row, 1968), 102.

18. It is difficult to find data in published sources which is compatable with Selected Acquisition Report data that breaks out individual program expenditures by RDT&E research category within the Five Year Defense Plan Research and Development Program. However, the R-1 RDT&E Program report published by the Office of the Assistant Secretary of Defense, Comptroller shows that Engineering Development Funds accounted for 64 percent of the total Air Force FY 1984 RDT&E budget. In FY 1983 it was 69 percent.

19. US, Office of Management and Budget, Office of Federal Procurement Policy, Proposal for a Uniform Federal Procurement System, 26 February 1982, 33.

20. This succinct discussion is more adequately treated in other publications. For a more complete discussion of the forms of competition see for example: Benjamin Sellers, "Competition in the Acquisition of Major Weapon Systems" (M.S. Thesis, Naval Postgraduate School, 1979), 40-50; William B. Williams, Guidelines for the Application of Competition, Rpt APRO 905 (Army Procurement Research Office, Ft Lee, Va., 1982), 22-97; George G. Daly, et al., The Effect of Price Competition on Weapon System Acquisition Costs, Rpt P 1435 (Institute for Defense Analysis, September 1979), 46-43.

21. US, Department of the Air Force, Project Ace: Findings and Action Plans (Air Force Systems Command, Andrews AFB, Md., 5 October 1973), 17.

22. Caspar W. Weinberger, "Competitive Procurement", Secretary of Defense Memorandum dated 9 September 1982.

23. Ronald Reagan, "President Directs Curtailment of Noncompetitive Contracting", White House Press Release, 11 August 1983.

24. Department of Defense Appropriations Act, 1984, P.L. 98-212, 8 December 1983, Sec. 797.

CHAPTER 2

PRICE COMPETITION: COST AND BENEFIT FACTORS

As stewards of the taxpayer's dollar, acquisition personnel must be concerned with the prudent expenditure of public funds. A decision to dual-source a weapon system during production results in additional costs and potential benefits to the government. If the decision is made on the basis of cost reduction, these costs and benefits must be quantified. They could then be compared to an estimate of what the sole-source price would probably have been in the absence of competition to identify the least-cost method of procuring the weapon system. Or if competition is instigated for other reasons, such as enhancing the production base, consideration of the costs and benefits will enhance the accuracy of the time-phased budget profile projections. They must also be used to evaluate studies that estimate the cost impact of competition on dual-sourced programs. This chapter presents a taxonomy of potential costs and benefits that, depending on dual-sourcing techniques chosen, might have an impact on weapon system cost and must therefore be considered in the dual-sourcing decision.

Cost and Benefit Elements

In his classic analysis of the weapons acquisition process, Frederic Scherer of Harvard University pointed out potential competition benefits when he noted that recurring costs in the World War II bomber program were lower in competitive as compared to noncompetitive procurements.[1] In contrast, he states that recurring costs for World War II fighter programs were higher in the competitive situation than were sole-source procurements. He also concludes that competition is not appropriate in all situations because of potential costs of dual-sourcing.

Scherer identifies the potential cost in transferring learning from the original producer, usually the developer, to the second source. Another cost occurs because of the learning phenomenon, a cost advantage accruing to the original producer. He also states that economies-of-scale can be upset by splitting orders and also by a company putting its best personnel on other programs. He notes the costs of additional tooling for second sources and also that they might change production tolerances from those of the original producer, thus (1) complicating the problem of field maintenance and (2) increasing logistics support costs.

Scherer identifies many pertinent elements that must be analyzed when considering dual-sourcing to obtain reduced costs through price competition. He does not, however, provide an exhaustive categorization of them or the statistical treatment required to obtain statistically significant conclusions, both of which are necessary to identify the total impact of dual-sourcing.

The impacts of dual-sourcing can be identified as those that can be quantified and those that cannot. Moreover, the quantifiable impacts can be divided into nonrecurring, recurring, other cost and profit. Figure 2-1 depicts each of these categories and the specific elements that must be considered within each category.

Each element will not impact equally on all competitive dual-source procurements. For dual-source competition to be implemented, two criteria must be satisfied. First, the weapon system description must be detailed enough for potential contractors to know exactly what is needed by the government. And second, there must be more than one contractor capable and willing to produce the weapon system. Weapon system complexity directly affects satisfaction of both criteria and in part determines the exact impact of the elements listed in figure 2-1 on a specific program. Moreover, the technique chosen to implement dual-sourcing will also affect these costs. A detailed discussion of each element will more clearly focus on the variable impact each can have on different programs.

Quantifiable Impacts

Nonrecurring Costs

The government incurs one-time, up-front nonrecurring costs to develop the second-source capability to produce the weapon system designed by the developing contractor. These costs include selection of the second source, its subsequent technical development, and other possible costs.

Second Source Selection. Source-selection costs are incurred by both the government and the contractor. They include the expense of preparing and responding to a request-for-proposals, evaluating the submitted proposal and accomplishing pre-award surveys of the second source to evaluate its ability to produce the weapon system.

The Air Force does not systematically collect data on its own overhead expense for accomplishing these tasks. However, costs include administrative salaries, travel expenses, and miscellaneous expenses such as printing and facilities for both issuing the request-for-proposals and evaluating proposals during the source-selection process.

The costs associated with contractor bidding and proposal expenses are identifiable. DOD cost principles allow recovery of bidding and proposal expenses as an overhead expense. As such, they are allocated across all contracts in the plant (or other profit center) in accordance with company procedures specified in their Cost Accounting Standards Disclosure Statement. Because of the allocation process, some bid and proposal costs will be paid for on other government contracts included in the allocation base and must be identified in the dual-sourcing decision. More will be said about the impact of the costs of one program on other government programs later in this chapter.

Quantifiables

Nonrecurring Costs

- Second-Source Selection
- Second-Source Development
    - Technical Data Package
    - Special Tooling and Test Equipment
    - Technical Transfer
    - First Article Testing
- Contingent Liabilities for Undepreciated Assets

Recurring Costs

- Cost/Quantity Relationships
    - Production Rate
    - Learning Curve
- Contract Administration Costs
- Technical Data Update

Other Costs

- Company Funded R&D
- Spare Parts
- Overhead Impact
- Logistics

Profit

Nonquantifiables

- Product Quality
- Cooperation
    - Technical Transfer
    - On-Going
- Time Delays
- Claims and Performance Failures

Figure 2-1. Cost and Benefit Impacts of Dual-Sourcing

Second Source Development. The financial commitment by the government to develop the second source usually involves the preparation and validation of the technical data package and its transfer to the second source. It can also include the cost of special tooling, test equipment, and first article testing.

The government pays for weapon system and manufacturing design during full-scale engineering development and, except for products or processes developed at contractor expense, owns rights to the technical data that it has paid to develop. However, the design and process data are usually dispersed throughout the contractor and subcontractor facilities and are not readily accessible for transfer to a second source. The government must pay for collecting and reproducing this data which in some cases can include 250,000 to 300,000 parts involving 20,000 to 30,000 drawings and an unknown number of processes.

A related data issue involves designs or processes developed by the contractor at its own expense. Proprietary information is the property of the developer and must be licensed or purchased by the government for use by another contractor.

The technical data package must be validated to assure its acceptability for production use. Either production by the sole-source contractor or examination by an external activity can accomplish this. For example, the Naval Avionics Center validated the data used for second-sourcing of the Phase III user ground equipment for the Navstar Global Positioning Satellite System.

The technical data package for less complex weapons might be sufficient for potential contractors to submit bids on the required system. However, in more complex systems, the potential second source might require technical assistance from the system developer using the leader-follower technique discussed earlier. This cost of technical transfer would also be accompanied by additional costs to the government for monitoring the transfer process.

There must be a quantification of the costs involved in the second-source developing its engineering and qualification models to demonstrate adequacy of the technical package and its ability to produce. Also, any contract costs incurred to increase second-source manufacturing efficiency through education buys must be considered to the extent their product cost is higher than if the product had been produced by the original source. Such cost differences could originate because of the economies of scale of the original producer. More will be said on this point later in this chapter.

Special tooling and test equipment is tooling and test equipment of such a specialized nature that it cannot be used for any purpose other than that for which it was purchased unless it is substantially modified or altered. And where adequate price competition is lacking, the government typically pays its full cost.[2] Therefore, to stimulate competition in follow-on procurements, the government generally must provide some to the proposed second source.

The quantity of government-furnished equipment required depends on the size and complexity of the program, the nature of the equipment, and the potential second-source contractor's equipment inventory. In most cases, there is no requirement for an exact duplication of the sole-source contractor's equipment lists since the second-source might own some of the required equipment. And, as in the case of education buys, these costs should not be considered to the extent they would be incurred to tool-up the original source to expand its production capacity in the absence of dual-sourcing.

Contingent Liabilities. The government might be contractually obligated for other costs to the original producer. For example, to encourage the developer to invest in efficient equipment, the government might have guaranteed reimbursement to the contractor if the contractor was not able to depreciate the investment over a specified production quantity. The existence of these contingent-liabilities for undepreciated assets on existing contracts must be considered.

Recurring Costs

Recurring costs are variable costs that occur during production and are dependent on the levels of production. Some are directly associated with the quantity produced. Others relate to contract administration and the costs for updating the technical data package.

Cost-Quantity Relationships. Costs of production can vary with both the rate of production and the maturity of the production process as measured by the cumulative quantity produced. The firm's production function specifies the production rate impact, and its learning curve measures the cost impact of a maturing production process.

Production Rate. The economic theory of production provides a theoretical basis for studying the impact of production rate. The production function specifies the relation between the quantity of inputs, or factors of production, and the product or output they produce. Each firm has a unique production function dictated by its factors of production and the technology it uses to transform its inputs into outputs. Hence if the efficiency of technology improves, more output should be generated from the same level of inputs. Factors of production include research and manufacturing equipment and facilities, research and manufacturing labor, and management.

Exploring this concept further, the factors of production can be both fixed and variable. In the economist's concept of short-run, at least one of the factors must be fixed and all others are free to vary. In the long-run, all factors are free to vary.

For purposes of example, assume a short-run scenario where land, equipment, and buildings are fixed and labor is a variable input. As output is expanded through additional labor inputs to the fixed plant and equipment, hence varying the proportions between these inputs, output is affected as shown by the total output line TP in figure 2-2.[3]

Total output increases up to point C. However, the rate of increase decreases between point B and C as measured by the slope of TP which represents the marginal return or additional product produced by varying the proportion of one input.

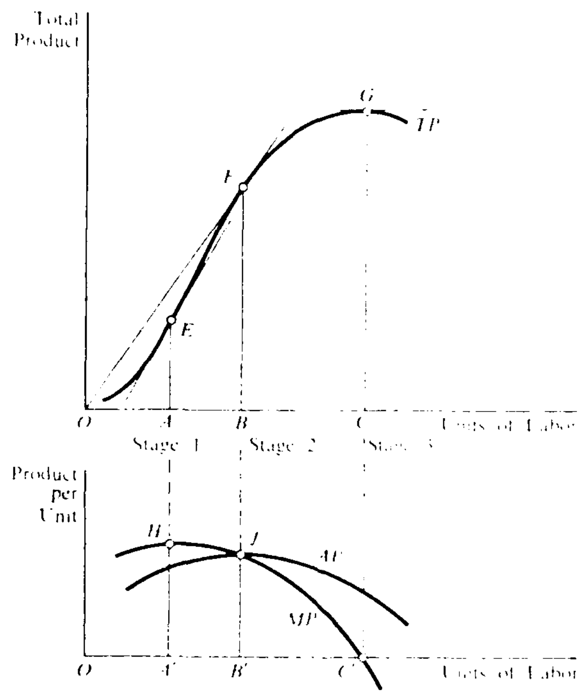


Figure 2-2. Variable Proportions

The concept of diminishing returns is more clearly seen in the lower half of figure 2-2 by reference to the average product (AP) and marginal product (MP) curves. Both MP and AP increase at first because more labor increases efficiency. Then output declines as people begin to get in each others way or there is nothing for them to do. Theoretically, at point D, marginal product actually decreases.

The marginal product of any quantity of a variable input depends on the state of technology and on the amounts and quality of the fixed inputs. If one firm had more efficient fixed inputs such as high-tech manufacturing equipment, marginal product would be higher than a firm with older, less efficient equipment. Even with such differences, the message is clear; namely, after some point in either case, total product would grow at a slower rate and marginal product would diminish.

The concept of marginal returns deals only with physical product. Cost impact of diminishing returns is shown by looking at the firms cost curves. Depicted in figure 2-3 is a firm's total variable cost curve (TVC) derived from the production function.[4] The cost and production functions are duals of each other. That is, the cost function can be derived from the production function and vice versa.

Total variable cost rises first at a decreasing rate indicating the higher marginal product of the inputs. It then rises at an increasing rate, indicating the decreasing marginal product. The slope of TVC is its marginal cost (MC).

These cost curves reflect only variable costs. The average cost curves (AC) must also consider average fixed cost (AFC) as depicted in figure 2-4.[5] As output is increased in the short-run, the average cost curve of a firm always declines to a minimum and then increases. The magnitude of decline depends on the proportion of fixed to total costs. If the proportion of fixed to total costs is high, the decline in average costs is rapid. And to the extent that firms have different production technologies and accounting systems, cost changes will be different between different firms.

The minimum point on the average cost curve represents the capacity at which the plant was designed to produce efficiently. Production at a rate either higher or lower than the minimum is accomplished at a higher average cost. How much higher is reflected by the slope of the curve which, as already stated, is unique to each firm.

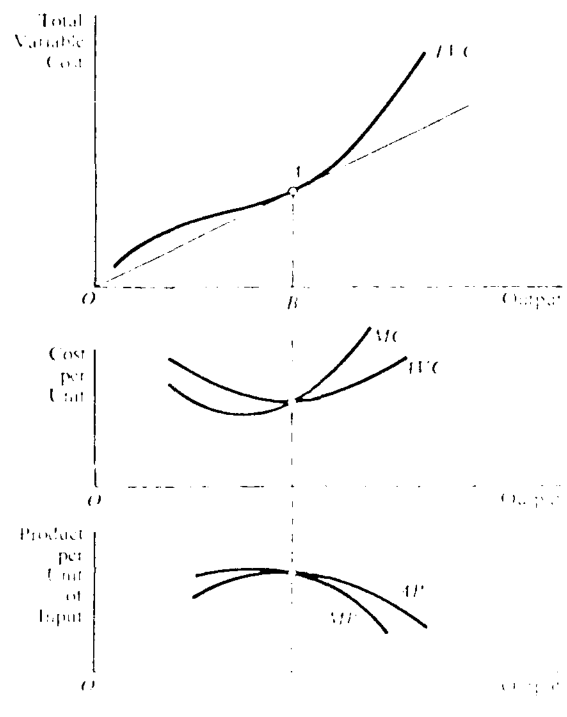


Figure 2-3. Cost and Production Functions

Studies of the acquisition process have identified the cost impacts of production-rate changes. The Defense Science Board in its 1977 Summer Study stated that very low rates of production substantially increase labor costs of airframe construction and assembly, and figure 2-5 graphically shows this relationship.[6] As illustrated a hypothetical

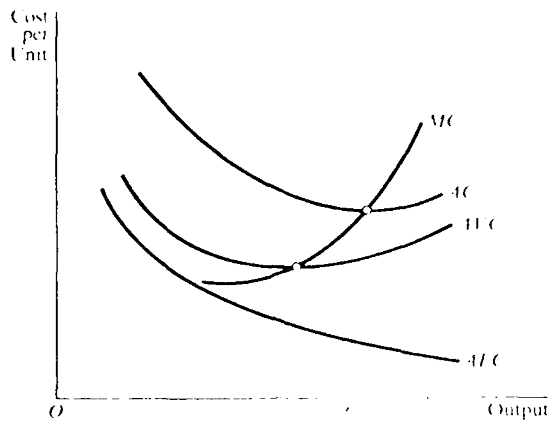


Figure 2-4. Short-Run Cost Curves

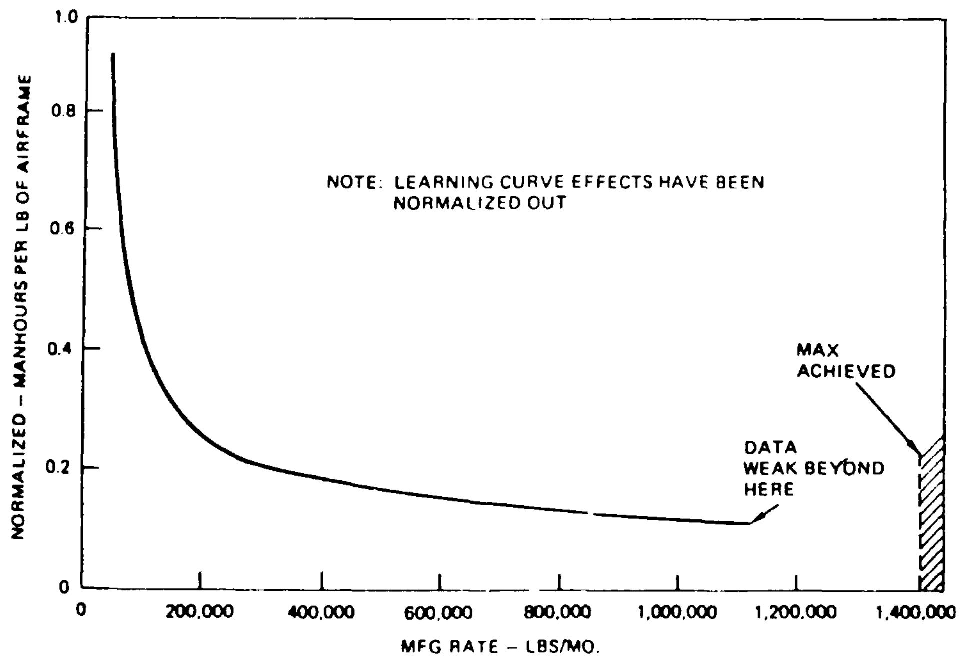


Figure 2-5. Effect of Production Rate on Commercial Airplane Airframe Cost

200,000-pound airframe produced at one unit per month has labor costs about 40 percent higher than the same airframe at two units per month.

The Affordable Acquisition Approach Study published by Air Force Systems Command in February 1983 studied 109 Air Force Systems and 600 reports on the acquisition process. One of the study's principle findings was that there had been a significant decrease in annual weapon system production rates. It estimated that a 30 percent reduction of production for a hypothetical budget program for FY 83-88 could create an increase in cost of from 6 to 14 billion dollars.[7]

Former Deputy Secretary of Defense Frank Carlucci initiated his 1983 Acquisition Improvement Program previously referred to in Chapter 1. Initiative 7 related to procuring economic production rates to spread fixed costs over a relatively large number of end items. Carlucci testified before the House Armed Services Committee that $2.3 billion could be saved by accelerating production rates on 18 programs as a result of this initiative.[8] Some of the programs included the Navy F/A 18 Hornet, Army's TOW anti-tank missile, KC-135 reengining, and the Mark 48 torpedo. This estimate of savings was subsequently increased by $86.2 million.[9]

The Army Procurement Research Office in a 1980 study reviewed research on the rate of production over the last 30 years and its impact on weapon system cost.[10] They conclude from their review of previous studies and their own case analyses that the most important contributor to increased unit cost under rate changes is an increased overhead allocation.

In summary the economic theory of production and published studies both point to a conclusion that production rate changes directly affect the costs of producing a weapon system. Therefore, in estimating the cost impact of competition, the effects of production rate changes must be separately accounted for.

Learning Curves. Learning curves are related to total production and represent a separate cost/quantity relationship that must be examined. This concept was first written about by T. P. Wright in 1936 when he related learning curves to the aircraft industry.[11] The concept tends to show that as total cumulative production doubles, labor hours required to produce an incremental unit are reduced by a constant percentage, such as 80 percent. This reduction occurs as the organization acquires a greater familiarity with required tasks, becomes more efficient with tools and procedures, and improves internal coordination until it reaches a plateau. Once this plateau is reached, only production rate effects will change the product and cost functions previously discussed.

Wright's original relationship was a power function of the form:

$$Y_b = a.b^{-x}$$

Where

b -- the total production
Y_b -- labor hours required for the b^{ith} unit
a -- labor hours required for first unit (is a constant)
x -- measure of the rate of learning

Transforming this model into logarithms you get:

$$\log Y_b = (\log a) - x (\log b)$$

This formulation is the equation of a straight line with slope (-x). Using the transformed data, the logarithm can be plotted on standard graph paper, or the untransformed data can be plotted on logarithmic coordinate paper.

The learning curve can be developed using cumulative average hours per unit or hours per unit as the Y axis and quantity produced as the x axis. Neither model has been empirically validated as being more advantageous. Consequently, choice of either model is at the discretion of the analyst. However, several authors have noted that models using the cumulative average formulation can be misleading because of the power of the averaging process to smooth the data and enhance the appearance of the curve.[12] This is particularly significant when there is only a small number of data points.

Other formulations of learning curves have been postulated. These have been set out elsewhere in the literature and are considered beyond the scope of this research.[13] However, we need to look at three points regarding learning curves.

First, it is better to use labor hours in the formulation of learning curves instead of labor dollars. Calculation of learning curves using labor dollars includes the effect of changes in wage rates and benefits over time. Unless adjustments are made to the data that exactly reflect these changes, the true effect of "learning" could be overshadowed. Using labor hours eliminates this potential problem.

A second point relates to the aggregation of the learning curves for the individual components of product cost: for example, manufactured parts, various subassemblies, purchased parts, and final product assembly. Each component has its own associated learning related to the opportunity for learning discussed earlier. Similar processes should be aggregated in order to increase the accuracy and reliability of estimates and to facilitate adjustments for changes such as production technology or product complexity over time.

A third point is that there is no agreement on a "fundamental law" of learning such as the existence of an 80-percent curve. Conway and Schultz conclude

> There are significant differences in patterns of progress for different industries, different firms, different products and different types of work. . . . No particular slope is

universal, and probably there is not even a common model. The contention that such exists is most difficult to defend either logically or empirically.[14]

Others have concluded, after empirical study, that "standard rates of [learning curve] progress can be safely applied only at the company or facility level until further research finds otherwise."[15] Moreover, differences in accounting can lead to different results between companies.

The important point of this discussion of the learning curve phenomenon for this research is that it exists. That is, over time a firm can reduce its cost of production in a potentially predictable manner. However, any reduction must be examined on an individual basis.

Contract Administration Costs. DAR 1-406 lists 72 functions to be performed by in-plant government personnel. Some of these functions are independent of specific contracts and relate to approval of contractor systems. However, some functions are contract-specific such as production surveillance, property administration, and quality control. Contract administrators are responsible for monitoring the additional contract provisions. Quality personnel must reject nonconforming material. And property personnel must monitor contractor accountability and maintenance of government property. Performance of these contract-specific functions at a second source can increase government personnel and associated costs.

Technical Data Update. A configuration control process must be established to update technical data packages used by the second source as engineering changes are made during production by the developing contractor. The Air Force Management Analysis Group, directed by Maj Gen Dewey Lowe, published its report in October 1983. It concluded that one of the major reasons for the lack of competition was the existence of outdated data caused by a lack of control of engineering changes.[16] Configuration management seeks to assure the currency of technical information held by the second source and its costs must be considered in the dual-sourcing decision.

Other Costs

The potential cost and benefit impacts discussed so far have focused on impacts experienced during the production stage of the specific program in question. Costs can also accrue to the specific program in both its research and development, and its deployment phases. And dual-sourcing can have an impact on the cost of other programs.

Research and Development Costs. As discussed in chapter 1, the research and development process is so costly that contractor selection is made early when weapon system technical description and expected cost are shrouded with uncertainty. Hence, source selection is accomplished

on perceived contractor technical approach and capability during early development efforts when a small percentage of total program costs is involved. Moreover, few weapons programs exist and producers fiercely compete for these limited opportunities.

Many studies of the acquisition process have identified the phenomenon of "buying-in," which has its origins in this technologically complex, cost uncertain economic structure of the defense industry.[17]

Buying-in occurs when a firm accepts no profit or incurs an outright loss on the initial development contract for a weapon system in order to put itself in a sole-source situation in full-scale engineering development and production, where the majority of costs are incurred. It then expects any losses to be made up by contract changes made during full-scale engineering development or production.

Some companies have stated that if the opportunity to make up the expenditure of their own research and development funds evaporates in the production stage because of competition, they will no longer incur these expenditures in anticipation of future business. For example, in a letter to the Air Force regarding Carlucci's initiative 32 on competition, Goodyear Aerospace Corporation acknowledges its buy-in strategy and notes its strategies will change if competition is introduced.[19] Specifically, they state that their research and development expenditures, which are usually amortized over the cost of product hardware, will be reduced to fit a potentially smaller aftermarket. Moreover, they note a similar spillover effect on subcontractors in that subcontractors will also recover all development costs on the initial buy instead of over the life of the program. Finally they note a reluctance to stimulate capital investment for plant improvement, machine tools, and test equipment. John Richardson, president of Hughes Aircraft Corporation, echoed these same feelings about dual-sourcing when he wrote, "Some contractors will reduce company-funded research and development expenditures usually recoverable over the cost of production articles."[20]

The potential for reduced company-funded R&D exists. If a given program's R&D is funded in part by contractors, and this funding ceases as contractors perceive an inability to recover their expenditures, the government is faced with the requirement for additional up-front funding as a result of its dual-sourcing decision.

Spare Parts. A second area outside the production stage that must be considered when evaluating a dual-sourcing decision is the impact of the availability of data during weapon system deployment which would allow for the competitive procurement of spare parts during weapon system deployment. A June 1983 audit by the General Accounting Office on the DOD high-dollar spare parts break-out program, where parts are bought from other than the system designer, concluded that break-out savings ranged from 44 to 68 percent. It stated, however, that competition or break-out is restricted because reliable data on actual part manufacturers are not available for break-out purposes throughout the Air Force.[21]

Undersecretary of Defense Richard De Lauer also noted that "one of the principal factors inhibiting competition in procurement of spares is the lack of technical data with appropriate rights for procurement purposes."[22] Deputy Secretary of Defense Paul Thayer reaffirmed this view to the secretaries of the departments on 15 March 1983.[23]

And finally the Air Force Management Analysis Group (AFMAG), discussed earlier, concluded that one of the key factors behind the low competition rate was the existence of inadequate or missing engineering data, for both prime and subcontractors.[24] One of the AFMAG recommendations was to develop an integrated spares acquisition and support plan contractual requirement during the full-scale engineering development competition. They felt purchase of technical data at this stage could help harvest potential savings from the competitive purchase of spare parts.

Overhead Impact. Indirect expenses can account for as much as 40 to 70 percent of contract expense and are those expenses which cannot be directly charged to a specific cost objective because the costs of accounting for them would outweigh any possible benefits to the government of charging them direct to a contract. For purposes of cost recovery, indirect expense is distributed using some presumed general relationship between it and its benefiting base. For example, engineering building depreciation might be allocated to cost objectives based on direct engineering hours or direct engineering dollars. The other two commonly aggregated overhead pools (in addition to engineering) are manufacturing and general and administrative expense.

Another contract cost that is allocated in a manner similar to overhead expense is an imputed return for facilities capital employed on a contract. Cost accounting standard 414 provides for a return on facilities employed in the performance of government contracts, with the facilities capital cost of money (FCCM) allocated to overhead pools. FCCM in-turn is allocated to benefiting cost objectives along with other overhead pools.

If the overhead allocation base for overhead pools is decreased, as when business is decreased by the split production quantities when dual-sourcing, the overhead rate goes up for all projects in the profit center. If these are government programs, the net cost to the government will increase in that facility. However, a decrease in the overhead rates of the second-source should occur as its allocation base increases. Cost principles are inexact and costs and rates are different between production facilities. Therefore, the net impact to the government on all programs of splitting requirements between two production facilities must be considered.

Another potential overhead impact that must be considered when evaluating analytical studies based on ex post data relates to a change in the contractor business base as a result of the capture by the contractor of other programs. This could cause the overhead rate to decrease on all programs. If these reduced rates were reflected in the

government's price obtained near the time of the introduction of competition, and the pre and post competitive prices were not adjusted to reflect this effect, the overhead reduction could inappropriately be attributed to the introduction of competition. For example the economic production rate for the F-15 is now lower at McDonnell-Douglas because they are also producing the F/A 18.

Nonquantifiable Impacts

While not specifically quantifiable, there are other favorable and unfavorable impacts on program outcome. J. C. McKeown identifies some of these other factors:

> Discussions on competition frequently lead to concentration on cost savings or price reduction. . . . For DOD, the benefits of competition extend beyond just cost reduction to include stimulation of innovation not only in technological and design areas, but also manufacturing; lower unit costs; satisfactory technical performance (and also quality); and a strengthened industrial base.[25]

Like McKeown, others have stated that the evidence supports the fact that quality and reliability of the product are improved under competitive conditions. And those interviewed during this research stated that cooperation from the original sole-source contractor increased under the threat of competition. They stated that competition resulted in engineering change proposals being submitted faster and the speed and quality of other communications being enhanced. Also, the advanced fighter engine program office cited the fact that in addition to lower prices, product warranties were obtained during competition which were more favorable than the original contractor would agree to under sole-source conditions.

Three other benefits accrue to the government under competition. First, competition makes it possible to have a surge capability at both the prime and subcontractor level exists (as in the case of the advanced fighter engine) that can be exercised if needed in the event of a national emergency. Second, sources are developed that potentially might compete for future weapon systems requirements. And third, the production base is dispersed which reduces the potential destruction of the total product production base.

Time delays associated with developing and qualifying the second source have a potential negative impact on program completion. And risk of failure for production by the second-source exists as was the case for the AN/UPM-98 radar test sets and AN/ARC-31 radio sets.[26] The risk of claims for inadequate data also exists. And finally, different manufacturing processes might lead to different tolerances or product characteristics that could cause future maintenance or logistics support problems.

The inability to quantify all costs and benefits does not mean the nonquantifiable factors should be ignored. The preferred method would be to identify all costs and benefits subject to quantification and to qualitatively describe the nonquantifiables. Subjective judgments could then be made by the program manager as to the cost effectiveness of competition considering both the quantifiables and nonquantifiables.

Statistical Considerations

Calculation of the net cost impact to the government of second sourcing involves recognition of three statistical and methodological considerations. First, contract data reflect then-year dollars and must be adjusted for inflation to isolate the effects of competition from those of inflation. Second, the flow of costs and benefits over time is not the same for all programs. And, because of the time value of money, these cash flows must be put on a common base. Third, the calculation of savings must be done using a common methodology. Each of these are discussed below.

Inflation

Inflation is the process of steadily rising prices which result in a decreased purchasing power of a given nominal sum of money. Demand-pull inflation occurs when aggregate demand increases faster than output. Cost-push inflation occurs when the prices of inputs, (e.g., labor) increase faster than their productivity. In conducting cost-based time series analysis, the effects of inflation must be identified in the financial data to more clearly examine the relationship of the relevant variables. If the data are not deflated, the relationship of the impact of competition and price could be masked and lead to erroneous conclusions.

Several indices are available for use in deflating contract data. Included are the gross national product deflator, wholesale price index, consumer price index, or sub-elements of each. Several other indices also exist that are applicable to missile systems. Whichever of the indices is chosen, it must reflect actual or projected inflation on the program or subsequent analyses will yield invalid results.

Discounting

As discussed earlier, high-level executive and legislative branch officials have strongly indicated that competition is good because it reduces net costs to the government. By investing up-front nonrecurring expenditures necessary to develop a viable second-source, they anticipate that incremental costs will be reduced by an amount greater than the up-front investment. However, because of the time value of money, the problem immediately surfaces as to the pattern of savings over time in relation to the up-front investment.

A simple illustration might clarify this concept. Suppose you are given the choice of the following investments and savings:

Investment	Amount	Year 1	2	3	4	Total Savings
A	75	20	20	20	20	80
B	75	80				80
C	75				80	80

All three yield a savings of $80 for an investment of $75. However, all the investments are not equally attractive. Investment B is the most attractive of the three because the investment is recouped in the first year. This provides an opportunity to reinvest the money and earn interest on the savings. Or if the money were borrowed, the principal can be paid back to avoid interest charges. Alternative C is the least attractive because for four years interest that could be earned by investing the money is foregone.

Pursuing this simplistic example further, hypothesize that the $75 was borrowed at 10 percent interest. At the end of the year, debt included the $75 principal and $7.50 interest for a total of $82.50. A comparison of the $82.50 cost to the $80 return dictates that the prudent person search elsewhere for a more lucrative investment.

In making prudent investment decisions, the present value of the entire cash flow must be compared to the present value of the necessary investment. The formula for determining present value of a cash-flow stream is:

$$PV = \frac{R_1}{(1+i)} + \frac{R_2}{(1+i)^2} + \ . \ . \ . \ + \frac{R_n}{(1+i)^n}$$

where

PV = present value
i = discount rate
R_1, R_2, . . . R^n = cash flow in years 1, 2, . . . n
n = duration of project

Applying this concept to the simplified example, the present value of investment A, assuming a discount rate of 10 percent, is:

$$V = \frac{20}{(1+.1)} + \frac{20}{(1+.1)^2} + \frac{20}{(1+.1)^3} + \frac{20}{(1+.1)^4} = 63.42$$

For investment B, the present value is $72.72, and for investment C the value is $54.79. Compared to the up-front investment, none of these alternatives appears favorable.

Federal policy requires the discounting of cash flows in the consideration of investment decisions. OMB Circular A-94 states:

> The discount rate prescribed in this circular applies to the evaluation of government decisions concerning the initiation, renewal or expansion of all programs or projects, other than those specifically exempted below, for which the adoption is expected to commit the government to a series of measurable costs extending over three or more years which result in a series of benefits that extend three or more years beyond the inception date.[27]

Exempted from the scope of the circular are water resource project decisions, the District of Columbia government, and nonfederal recipients of federal loans or grants. Also excluded are secondary decisions made to implement a program after a favorable decision to initiate, renew, or expand the program is made using the provisions of the circular. In the opinion of this researcher, investments to reduce the costs of weapons systems are not exempted from this requirement.

The circular specifies a discount rate of 10 percent that must be applied to the deflated dollar flow of program costs and benefits over time. That is, the 10 percent figure is to be applied to inflation-adjusted cash flows.

A benefit-cost ratio is then calculated using the formula:

$$\text{Benefit-Cost Ratio} = PV_b \div PV_c$$

where

PV_b = Present value of benefits
PV_c = Present value of costs

A ratio of greater than one would be a favorable ratio, with those investments with higher ratios yielding the better return. In our simple example, the benefit-cost ratio of alternative A is .79, alternative B is .90, and alternative C is .68.

The concept of discounting has become increasingly important given current economic conditions. Present budget deficits are expected to be greater than $180 billion a year for the next several years. Therefore the government will have to borrow its funds in the money markets to finance expenditures at an interest rate most likely greater than 10 percent. Moreover, 16.1 percent of the federal budget presently consists of interest on the public debt. Pressures are mounting to cut the debt and weapon system planners should be sensitive to budget reduction pressures. It escapes logic to borrow money at a given rate of interest, use it to develop a second-source for the purpose of decreasing weapon system cost, and receive a rate of return on investment that is less than the loan interest rate. Discounting as a technique considers the alternate investment opportunities and factors these into the cost/benefit cash flow stream over time.

Savings Calculation

The calculation of percentage savings attributable to competition should include all the variables discussed so far, including recurring and nonrecurring costs. The percentage savings calculation could take many possible forms, and the reader is cautioned to understand what percentage is being referred to when a percentage is cited in a study. For example, table 2-1 lists savings attributed to the Shillelagh missile in one study.[28]

Table 2-1
Diversity of Savings Estimates on the Shillelagh

22 percent savings on competitive buy-out, recurring costs only, presumably in 1972 dollars. Sole-source learning curve exponent of -0.233 reported in APR 078 used to project sole-source price.

9 percent savings on all post-competition production, recurring costs only, in 1972 dollars. Sole-source learning curve exponent of -0.233 from APR078.

-1 percent loss on first competitive split-buy, presumably in 1972 dollars, using the APR078 exponent of -0.233 for the sole-source learning curve.

-4 percent loss on all post-competition production, recurring costs only, using a learning curve exponent (value not given) derived by IDA79 from APR078 data. Presumably 1972 dollars.

-8 percent loss on all post-competition production, recurring costs only, using cumulative average price learning curve exponent estimated at -0.390. Constant dollars, year not given.

-14 percent loss on first competitive split-buy using learning curve exponent (the value is not given) derived by IDA79 from APR078 data. Presumably 1972 dollars.

Differences in savings estimates can result from (1) the use of different data, (2) differing statistical methods, or (3) differing definitions of what savings are. The numbers reflected in table 2-1 were calculated by The Institute for Defense Analysis (IDA) to show the sensitivity of results to these problems. The first two problems will be discussed in depth in the next chapter through a review of published studies. The final one is discussed here.

The most useful formulation of savings is:

$$S = \frac{PV_b - PV_c}{PV_s} \times 100\%$$

where

S = percentage savings
PV_b = present value of all competition benefits
PV_c = present value of all competition costs
PV_s = present value of post competition production had the system been procured sole-source.

The numerator is formulated to reflect the net impact to the government considering all cash-flow impacts of competition. The denominator reflects what the cost of the remaining program would have been in the absence of competition. Although some studies have used total program cost as the denominator, precompetition costs are not relevant for decision making. They are sunk costs that do not affect either the sole source or competitive outcomes.

Conclusions

There exist a plethora of costs and benefits that must be considered in the dual-sourcing decision itself and budgeting for programs that are dual-sourced. These include nonrecurring, recurring, and other program specific impacts in the production stage of the program. Moreover, competition might also affect the cost of the program's development and deployment stages. And finally, other government programs might also be influenced.

Calculation of the net impact of dual-sourcing involves adjustment of historical data for the impact of inflation. Moreover, the cash flow over time must be discounted to reflect the time value of money and to obtain the highest return on money invested to develop the second source. And finally, the reader is cautioned that the savings percentage calculation varies in different studies due to the differences of data, methods, and basis of savings calculation.

Chapter 3 now turns to a review of ex ante studies. Using the criteria developed in Chapter 2, it reviews the study data, methods, and conclusions. It also reviews published critiques of the studies.

NOTES

CHAPTER 2

1. Frederic M. Scherer, The Weapons Acqusition Process: Economic Incentives (Boston: Harvard University, 1964), 125.

2. See DAR 13-305.1(B).

3. Donald S. Watson, Price Theory and Its Uses (Boston: Houghton Mifflin Company, 1972), 188.

4. Ibid., 222.

5. Ibid., 224.

6. US, Defense Science Board, Report of the Acquisition Cycle Task Force, 1977 Summer Study, 15 March 1978, 29.

7. US, Department of the Air Force, The Affordable Acquisition Approach Study, Executive Summary (Air Force Systems Command, Andrews AFB, Md., 1983), ES 7.

8. Carlucci testimony before House Armed Services Committee, 9 February 1982.

9. "DOD Hikes Economic Production Rate Savings Estimate," Aerospace Daily, 27 May 1982, 149.

10. Charles H. Smith, Production Rate and Weapon System Cost: Research Review Case Studies, and Planning Model, Rpt APRO 80-85 (Army Procurement Research Office, Ft Lee, Va., 1980).

11. T. P. Wright, "Factors Affecting The Cost of Airplanes," Journal of Aeronautical Science, vol. 3, no. 2, February 1936.

12. For example, see R. W. Conway, and Andrew Schultz, "The Manufacturing Progress Function", Journal of Industrial Engineering, January-February 1959, 39-54 and Samuel L. Young, "Misapplications of the Learning Curve Concept", Journal of Industrial Engineering, August 1966, 275-282, in Learning Curves, Theory and Applications Rivinder Nanda, and George L. Alder, editors, (Norcross, Georgia: Institute of Industrial Engineers Inc., 1982).

13. It is not the intent of this research to enter into the academic dialogue relating to the form and the advantages and disadvantages of each formulation. Two good references for additional information include Nanda and Alder, Learning Curves; which has an excellent bibliography on the subject; and Harold Asher, Cost-Quantity Relationships in the Airframe Industry. RPT R-291 (Santa Monica, The RAND Corporation, 1 July 1956.)

14. Conway and Schultz, Learning Curves, 53.

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17. Fred Garza, "Impact of competitive Procurement on Configuration Control", PMC 77-1 (Defense Systems Management College, Ft Belvoir, Va., 1977) iii.

18. This strategy has been observed by many students of the acquisition process. See for example Peck and Scherer, Weapons Acquisition; J. Ron Fox, Arming America: How the US Buys Weapons (Boston: Harvard University, 1974); and Jacques Gansler, The Defense Industry (Boston: MIT Press, 1983).

19. R. A. Fredrick, Business Development Representative, Aircraft Wheel & Brake Division, Goodyear Aerospace Corporation, Akron, Ohio. Letter of 24 March 1983, regarding the break-out of critical parts to Competiton Advocate, Ogden Air Logistics Center.

20. John Richardson, "How 'Second-Source' Contracting Undercuts Carlucci-Initiative Goals", Government Executive (September 1982), 32.

21. US, General Accounting Office, Air Force Break-out Efforts are Ineffective, Rpt GAO/PLRD 83-82, 1 June 1983.

22. Richard De Lauer, Under Secretary of Defense Letter, 19 October 1982, Subject: Competitive Procurement of Spare Parts.

23. Paul Thayer, Deputy Secretary of Defense, Letter 15 March 1983, Subject: Replenishment Parts Procurement.

24. AFMAG, Spare Parts, 2-17.

25. John C. McKeown, "Increasing Competition in the Acquisition Process", Concepts 5, Summer 1982, 26.

26. Myron G. Myers, et al., Price Competition in the DOD (Logistics Management Institute, Washington, September 1982), 2-4.

27. Executive Office of the President, Office of Management and Budget, OMB Circular A-94, "Discount rate to be used in evaluating time distributed costs and benefits", 27 March 1972.

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CHAPTER 3

COMPETITION STUDIES: PANACEA OR PANDORA'S BOX?

Robert McNamara, while secretary of defense, testified before the House Committee on Armed Services in 1965 that when the Department of Defense dual-sourced weapon systems it saved an average of 25 percent.[1] And former Deputy Assistant Secretary of Defense Jacques S. Gansler testified before the House Budget Committee as recently as 8 November 1983 that "dual-sourcing experiments tried in the past have yielded an average net program cost savings of 30 percent."[2] While these figures lack valid empirical support, many studies have been published which analyze, ex post, the cost impact of dual sourcing weapons acquisition and posit a predictive model of expected savings in dual-source decisions. Other reports critique the data and methods used in these studies. The balance of this chapter explores chronologically the more substantive studies and the critiques by reviewing their major data, methodology, conclusions, and any model they propose to predict competition savings on future procurements.[3] It also presents this author's conclusions regarding the predictive validity of these studies. (Usefulness for assisting in making future second-sourcing decisions.)

Studies

Electronics Command 72

One of the first systematic studies of the effects of competition was done by the Army Electronics Command (ECOM) in 1972.[4] This study compared the pre- and post-competitive price of 13 electronic items having an average price of $2,822 and ranging between $290 and $10,000 per item. The items first entered production between FY 1958 and FY 1967.

The methodology used was:

$$\text{Percent Savings} = \frac{\text{Last sole-source price - first competitive price}}{\text{Last sole-source price}}$$

Unit price reductions for recurring costs averaged 53 percent when competition was introduced and ranged from 12 to 78 percent. Savings were attributed to all procurements. The study neither adjusted savings prices for inflation, nor considered nonrecurring costs. Nor did it consider production rate changes and learning from previous buys. Additionally, it did not discount cash flow.

The study made multiple regressions to find a predictive model using competitive lead time over sole-source lead time, competitive quantity over sole-source quantity, and competitive delivery rate

(quantity per month) over sole-source delivery rate as predictors of price reductions. Unable to establish any relationships, the researchers concluded:

> To further pursue the attempts of finding more significant causal relationships among lead time, quantity, and delivery by regression techniques appears futile. It can almost be concluded that the desired relationship is severely clouded by other variables that would be difficult to quantify. Also, the number of . . . items making the transition from sole-source to competition each year is small, and to accumulate a large enough sample to provide sufficient degrees of freedom if the variable list were expanded would span many years.[5]

Notwithstanding this caveat, however, they concluded that for planning purposes a conservative estimate of savings is from 25 to 30 percent.

Yuspeh 73

Larry Yuspeh performed a 1973 study of 20 items for the Joint Economic Committee's Subcommittee on Priorities and Economy in Government.[6] Average price of the 20 items was $14,360 in 1970 dollars, with a price range of $891 to $92,249 in inflation-adjusted dollars.

The study calculated price changes under competitive pressures of recurring production costs as follows:

$$\text{Percent Savings} = \frac{\text{Last sole-source price - first competitive price}}{\text{Last sole-source price}}$$

The study found that there was an average of 51 percent savings on all programs analyzed, with the range of savings being from 16 to 80 percent. While the researcher recognized that learning curves exist, he did not factor a learning curve effect into the savings estimate. Data are inflation-adjusted and Yuspeh pointed out that the learning curve flattens out in competitive instances. He recognized the existence of nonrecurring costs but did not consider them in offsetting gross savings in his analysis. He concluded that winner-take-all awards resulted in greater savings than did split awards.

While not developing a predictive methodology, he did assert that his report "establishes both the advantages and feasibility of competitive procurement of sophisticated military equipment."[7]

IDA 74

In 1974 the Institute for Defense Analysis (IDA) analyzed competitive procurements of 19 weapons systems with an average price of

$6,954 with prices ranging from $422 to $87,636 in 1970 dollars.[8] However, the Talos guidance and control system cost $87,636. Deleting this system from the sample leaves the high end of the range at $6,812.

Program savings were calculated using the following methodology:

$$\text{Percent Savings} = \frac{\text{Sole-source price extrapolated down learning curve} - \text{First competitive price}}{\text{Extrapolated sole-source price}}$$

The unweighted mean of recurring cost savings was 36.8 percent, with a range from 0.2 percent cost increase to a 60.8 percent savings.

This study was the first to recognize contractor learning by using learning curve analysis in analyzing a repetitive production situation analysis. The study did not consider nonrecurring costs or production rate changes. It did adjust data for inflation. IDA used multiple regression analysis to examine in a predictive sense the effect on post-competition unit-price reductions of four variables: the exponent of sole-source learning curve, the ratio of competitive to sole-source quantities, type of competition, and number of bidders as a measure of the intensity of competition. Three statistically significant relationships were reported:

> (1) The steeper the progress-curve slope the less that is likely to be saved; (2) On the first competitive buy, maximum savings are achieved with a buy-out competition, minimum savings with a 50/50 split (each competitor gets half of the total); (3) Unit-price reduction is negatively correlated with the ratio of the number of units bought under the first competitive award to the total number of units produced under all the sole-sourced awards.[9]

No statistically significant relationship was found for another variable: the number of bidders. And the study did not develop a regression equation for use in a predictive mode using the statistically significant variables.

APRO 78

The Army Procurement Research Office (APRO) studied 16 Army and Navy systems that had been dual-sourced with an average price of $13,138 in FY 1972 dollars, and the prices ranged from $589 to $85,805.[10] Excluding the top three items, the average price was $4,950.

Savings were calculated as a percent of total program costs as follows:

$$\text{Percent Savings} = \frac{(\text{Extrapolated sole-source learning curve price} - \text{1st competitive buy}) \times \text{competition quantity}}{\text{Total Program Cost}}$$

Unit recurring-price reductions averaged 10.8 percent, ranging from a net increase in cost to the government of 13.2 percent for the Mark 46 Torpedo to a savings of 51 percent for the Shrike missile. The methodology considers inflation and contractor learning, and it adjusts for contract changes. It does not include production rate, nor does it discount cash flows. The use of total program cost as a base for savings calculations results in lower savings calculations than other studies because competition savings are compared to total program cost instead of the proportion of the program competed or the first competitive buy.

One problem identified in the APRO 78 analysis involves using price data to develop learning curves when price data can contain both recurring and nonrecurring costs. While the analysis uses other sources of cost information to filter out these costs, the data are imprecise. For example, only $746,100 is considered as nonrecurring technical assistance costs to the second source from the prime on the Shillelagh missile. Others have estimated the cost of technology transfer in the millions of dollars on other programs.[11]

The predictive methodology of the APRO 78 analysis--called their forecasted savings methodology (FSM),--consists of three parts. Part one involves a competition screen, part two is the forecasted savings estimate, and part three is the competition index.

The competition screen consists of 12 elements influencing competition against which a potential dual-source award must be evaluated to see if it is worth pursuing a dual-source strategy. These elements are shown in table 3-1.

Table 3-1
Factors Influencing Competition: The Competition Screen

1. Prohibitively high initial start-up costs
2. Lack of a definitive technical data package
3. Proprietary data--technology transfer
4. Congressional interests--budget constraints
5. Inadequate production quantities
6. Economic climate
7. Length of planned production cycle
8. Critical or scarce materials
9. Nonconformance to cost-accounting standards
10. Special tooling/test equipment

Table 3-1--continued

11. Testing requirements

12. Government/industry-wide cash flow problems

The second step of the FSM for those items that pass the competition screen is to estimate expected savings. Data relating to savings from the 16 systems in the report were used to obtain the following predictive equation: $AUP = PUP^{.975}\ ROQ^{-.157}$

Where:

AUP = actual unit price for all production that occurred after competitive buy-out

PUP = projected unit price of sole-source progress curve over the post-competitive buy-out production

ROQ = ratio of post-competitive buy-out production to total program production quantity

A competition index is the third step and involves an evaluation of the qualitative aspects that can influence the amount of savings. These aspects are listed in table 3-2.

Table 3-2
Competition Index

1. Perception of Competitive Position

   a. Production experience
   b. Capacity
   c. Age of facilities
   d. Area wage rates
   e. Union

2. Anticipated Future Requirements

   a. United States
   b. Foreign military sales
   c. Spinoffs
   d. Other components

3. Economic Conditions

   a. Current
   b. Future

4. Company Goals

   a. Immediate
   b. Long-range

Table 3-2--continued

5. Risk-Assumption

    a. Technical risk
    b. Quality of technical data package

6. Capital Investment

    a. Dollar value required
    b. Use of government-furnished equipment
    c. Type of equipment

7. Make-or-Buy Considerations

    a. Sole-source subcontractors
    b. Government-directed subcontractors

8. Other

    Types of contracts
    Should cost
    Value engineering

Each factor is given a weight from +10 if the factor has an "extremely strong increasing influence" on the benefits of competition to -10 if the factor has an "extremely strong decreasing influence," or each factor can be assigned any weight between the extremes. A weighted average of the individual factor scores based on their importance to the specific system is calculated and a subjective judgement made.

IDA 79

The Institute for Defense Analysis' second study was published in 1979 and summarized 31 cases from the three studies just discussed.[12] Cumulative average unit price was $17,675, with prices ranging from $138 to $177,622.

Savings were calculated as follows:

$$\text{Percent Savings} = \frac{\text{Sole-source price extrapolated down learning curve - contract price}}{\text{Projected Sole-Source Price}}$$

This study estimated savings averaged 35.1 percent on all post sole-source buys and ranged from a 23 percent cost increase to a savings of 64 percent. It did not consider discounting, did not make rate adjustments, and considered only some of the nonrecurring costs. While data were inflation-adjusted, the methodology was not included.

The study developed a forecasting model as follows:

$$FSFB = \frac{-(1+FQ/SSQ)^{SSS} - .414}{1-(1+FQ-SSS-1)^{-SSS-1}}$$

Where:

FSFB = fractional savings on future buy

FQ = quantity procured competitively

SSQ = sole-source quantity

SSS = sole-source learning curve slope

The equation is the cumulative average price variant of the standard learning curve equation. Gross savings on competitive quantities are predicted as a function of the ratio of total quantity to sole-source quantity, the known sole-source slope derived from cumulative average prices, and the mean (-.414) of competitive slopes from its sample of 31 items.

The study concluded that the savings forecasting model is only a moderately successful predictor of actual savings. It stated, however, that for planning purposes, projections of post competition savings are 10 percent for split award buys and 20 percent for buy-outs. And they also add this caveat to their findings:

> It is in-fact likely that no precise and stable predictive relationships exist; there are so many dimensions of variation surrounding each procurement (e.g., technology, market conditions) that each system is to a considerable extent unique."[13]

TASC 79

In 1979 The Analytic Sciences Corporation (TASC) was selected by the Joint Cruise Missile Project Office to develop a method to estimate comparative production costs for sole-source and competitive dual-source production strategies.[14] TASC reanalyzed 45 procurements that had previously been reported. In contrast to the previous studies, which characterized the reduced cost as a shift down in the learning curve under competitive circumstances, TASC characterized the savings as an immediate downward shift in the learning curve at the point of competition, due to cost-and-profit reduction, and a rotation or steepening of the curve as the previously sole-source producer introduces efficiency into the production process as shown on figure 3-1. The standard power function was used:

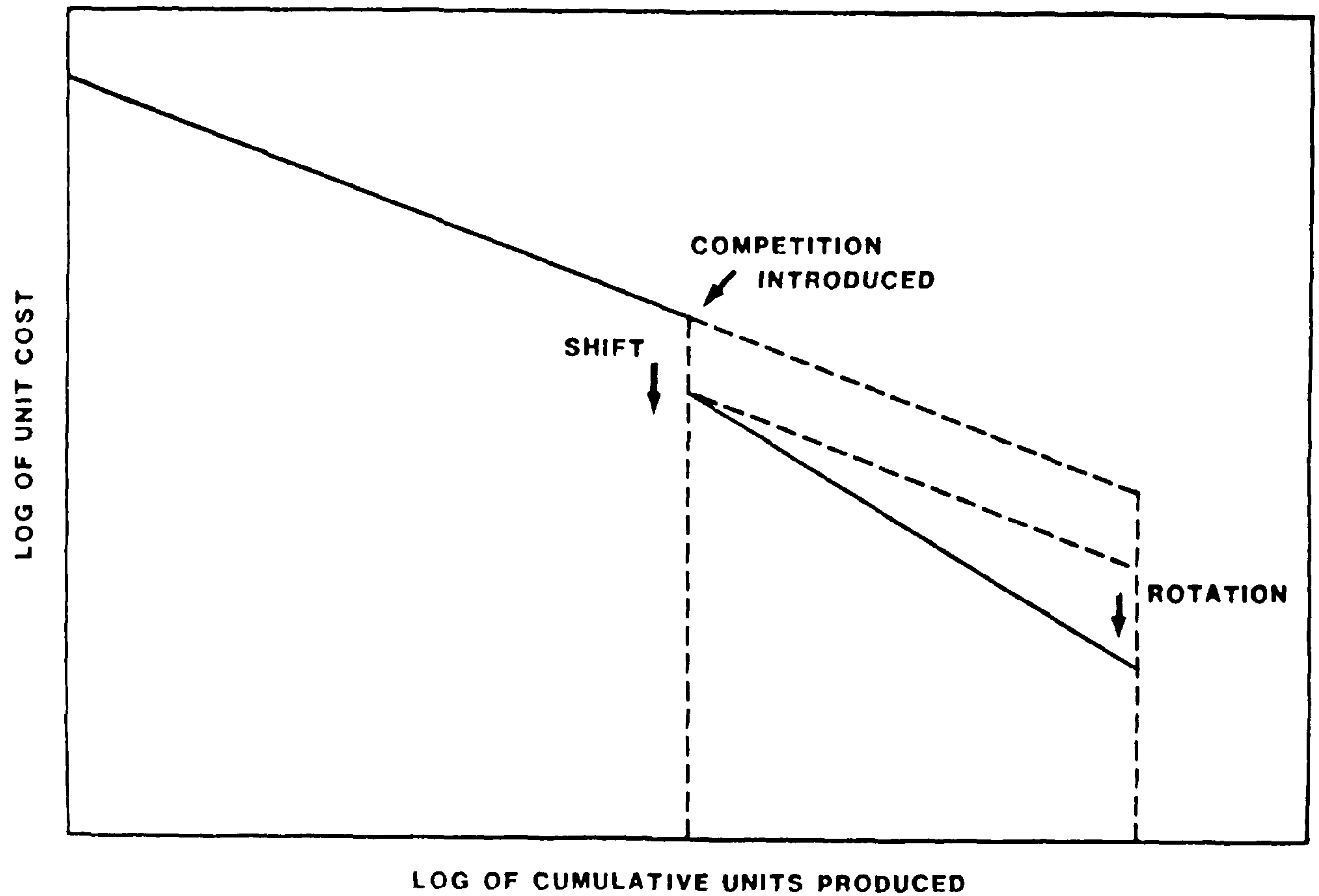

Figure 3-1. Effects of Competition on Cost Improvements Curve Characteristics

$$Z = AX^{B}$$

Where:

Z = unit cost of the Xth item produced

A = first unit cost

X = cumulative quantity produced

B = parameter for slope of the quantity/cost curve

Savings were calculated as:

$$\text{Percent Savings} = \frac{\text{Sole-source price extrapolated down learning curve - first competitive price}}{\text{Sole-Source Price Extrapolated}}$$

The study estimated the average gross savings for recurring costs from both the shift and rotation effects at 33 $\pm$ 6 percent. TASC also found that a combined profit-and-cost reduction (shift) of 12 $\pm$ 2 percent was probably too low, and estimated an improvement (rotation) of 5 $\pm$ 2 percent. The analysis was inflation-adjusted, using an unspecified index, but did not consider production rate. The reported recurring cost savings ranged from an increase in cost to the government of 16.2 percent to a savings of 67.7 percent.

TASC 81

In 1981 The Analytic Sciences Corporation published a further study that projected comparative sole-source and competitive dual-source production cost estimates for sea-launched and ground-launched cruise missile airframes.[15] TASC modified its 1979 analysis and included projected impacts of both production rate and total production quantity (learning curve) variation.

The model's basic formulation is: $Z = AX^{B} Y^{C}$.

Where:

Z = unit cost of the Xth item produced

A = 1st unit cost

X = cumulative quantity produced

B = parameter for slope of the quantity/cost curve

Y = some measure of production rate

C = parameter of slope of the rate/cost curve

The study developed estimates of the parameters for five tactical missile systems using a least-squares fit of the exponential formulation to observed data. The methodology involved finding the solution to a set of nonlinear equations in five unknowns. It assumed successive iterations from an initial starting point to minimize squared error using Newton's method for finding the roots of a nonlinear function.[16] It calculated learning curves using cumulative units, and it used lot size as a proxy production rate. Using this procedure, which was inexactly specified in its report, the study made parameter estimates as shown in table 3-3. In making these calculations, the study assumed the shift and rotation of the curve will not occur until the point of competition.

Those making the study contend their second model, which includes the effects of production-rate variations, is substantially different from their first model, which does not allow for production-rate effects. Therefore, they stated that comparing parameters between models is essentially meaningless.[17]

They developed a predictive theoretical framework which they described as "both theoretically and intuitively pleasing." It is represented in figure 3-2.[18] Curve S_1 depicts the cost improvement curve of the sole-source producer (with variations due to production rate removed) in a noncompetitive environment. Curve S_2 shows the shift and rotation of the cost-improvement curve after competition is introduced. Curve S_3 is a theoretical construct of the optimal or best-cost improvement curve one might observe if the manufacturer were under continuous competitive pressure from the outset. It is obtained by beginning with the historically derived, noncompetitive first-unit cost and ending when the curve achieves parity with the competitive last-unit cost. It represents what TASC states might have happened had the original producer been under continuous competitive pressure from the outset. TASC has developed separate curves for both missile and electronic systems.

TASC researchers use their model in a predictive mode by using a proxy production rate and program-specific, sole-source learning curve data. While they did not specify their formulation, it appears to be as follows:

$Z = A\ [\exp\ (d \cdot DC)]\ X^{(b\ \times\ f \cdot DC)} Y^{c}$.

Where:

Z, A, X, Y are above

DC equals binary with a value of one when lot is procured under competition and zero otherwise.

Using this formulation, they assume that the second source begins producing at the same first-unit cost as does the first producer, but

Table 3-3
Summary of Results

Data	First Unit Cost	Cost Imp. Curve Parameters		Prod. Curve Parameter	Shift	Rotation	Quantity Produced	
		Sole-Source	Competitive				Prior to Comp.	After Comp.
Sparrow (Raytheon)	415,336	.846	.777	.985	4.3%	8.1%	1,625	3,408
Sparrow (G. D.)	450,186	.874	.759	.923	-0.4%	13.2%	505	2,060
Bullpup	53,416	.823	.726	1.004	12.6%	11.8%	7,520	29,512
TOW	5,297	.991	.644	1.007	15.5%	35.0%	15,750	55,837
Sidewinder	16,021	1.047	.684	.819	16.3%	34.7%	11,285	29,908

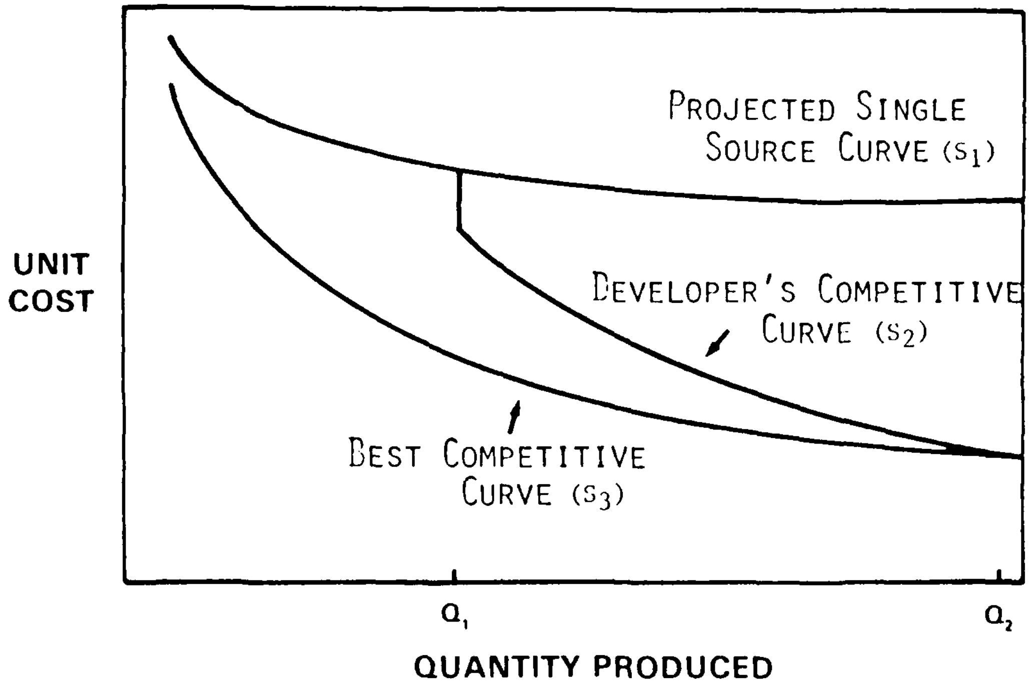

Figure 3-2. Cost Improvement Curves with Variations Due to Production Rate Removed

that his cost-improvement rate is four percent steeper than the first source. They then assume that at the point of competition a shift and rotation would be observed on the cost-improvement curve of the first source. The magnitude of the shift and rotation is assumed to be sufficient for the company to eventually reach cost parity with the optimum cost-improvement curve. (Point Q_2 in figure 3-2 is derived from historical data using the TASC formulation.)

This TASC study does not consider nonrecurring costs, nor does it discount savings over time. Additionally, it does not consider potential impacts on other programs.

SAI 82

In 1982, Michael Beltramo and David Jordan of Science Applications, Incorporated (SAI) conducted a three-part study for the Navy on the impact of dual sourcing.[19] They reanalyzed seven missile and bomb systems that had previously been analyzed. Sole-source costs were estimated by projecting down the sole-source learning curve. To show the sensitivity to percent savings calculation methods, they calculated savings using three cases:

Case one--The first competitive lot price expressed as a percentage of estimated sole-source lot price.

Case two--The total competitive recurring production cost with estimate sole-source cost.

Case three--The estimated savings for total program by the percentage of the total quantity completed.

Using this methodology, the study considered some nonrecurring costs with the results shown in table 3-4. Differences in estimated costs or savings of the three cases range from 20.5 to 27.5 percent additional costs to the government over the sole-source estimated amounts, depending on the calculation methodology.

The study did not consider production rate nor did it discount cash flows over time. Some nonrecurring costs were considered, and some government-related costs, while acknowledged, were not quantified.

The authors did not outline a predictive model, but they did qualitatively explore the following six criteria as questions to ask when considering a program for dual-sourcing:

1. Does the government own the data rights?

2. Is the item to be produced technically complex with respect to design and manufacturing processes?

3. If the item is complex, would technical assistance be required from the initial source to establish an effective second source?

4. What is the total required quantity? How many units would be produced by the initial source prior to technology transfer? Prior to dual-source competition? How many units would the second source produce during educational buys?

5. What is the maximum quantity to be produced in a year? Can production efficiency be optimized at half of that quantity?

6. Does the initial source have traditional rivals for the item to be produced? Who are they?

<u>Greer and Liao 83</u>

Previous studies quantified savings and attempted to correlate savings with a number of parameters: sole-source learning curve slope, percentage of total program completed, product complexity, and other predictive variables. In addition, Yuspeh 73 and IDA 79 addressed the differences in savings between split-buy and buy-out strategies. None, however, identified specific causative variables; that is those that

Table 3-4
Sparrow AIM-7F Actual vs Estimated Life Cycle Costs
Related to Dual-Source Competition (millions)

	ACTUALS			Estimated Sole Source Costs: Raytheon		
	Raytheon	GD	Total	Case 1	Case 2	Case 3
Nonrecurring	(21.8)	(40.9)	(62.7)	(24.0)	(24.0)	(24.0)
Data Package Preparation	8.9	—	8.9	—	—	—
Planning	—	1.7	1.7	—	—	—
Tooling and Test Equipment	12.9	26.3	39.2	24.0	24.0	24.0
Qualification of Second Source	—	12.9	12.9	—	—	—
Recurring*	531.0	227.1	758.1	632.5	619.7	656.9
Totals	552.8	268.0	820.8	656.5	643.7	680.9
Difference Between Actual Dual-Source and Estimated Sole-Source Costs Absolute Percent				+164.3 + 25.0%	+177.1 + 27.5%	+139.9 + 20.5%

*Does not include government costs which are probably higher for dual-source competition.

caused the difference of magnitude of savings or loss on a program. Willis Greer and Shu Liao attempted to measure the correlation of the magnitude of savings with contractor "hungriness."[20] As a measure of hungriness, they used capacity utilization for the aerospace industry and correlated this measure with savings or loss on missile programs. Their models are formulated:

$$\text{Production Rate Model:} \quad P = KQ^{a}R^{b}$$

$$\text{Capacity Utilization Model:} \quad P = KQ^{a}\,U^{c}\,\exp(dm)\,\exp(fn)$$

Where

P = average price

Q = midpoint quantity of buy

U = smoothed utilization percentage for industry

M = 1 if the buy is under dual-sourcing, 0 otherwise

N = 1 if the competition is winner-takes-all, 0 otherwise

a, b, c, d, and f, are parameters

Note that the second model substitutes capacity-utilization for the production rate. Greer and Liao concluded that the capacity-utilization model is a better predictor of savings with the following parameter values and nonsignificant variables deleted:

For the original source:

With median values:

$$P = KQ^{-0.278}U^{+1.250}e^{-0.101M}e^{-0.854N}$$

With mean values:

$$P = KQ^{-0.260}U^{+1.765}e^{-0.201M}e^{-0.854N}$$

The second source models are:

With median values:

$$P = KQ^{-0.174}e^{-.520N}$$

The study concluded that it is best to compete when capacity utilization is below 80 percent, as shown in their data arrayed in table 3-5:

Table 3-5
Relation of Savings and Capacity Utilization

Procurement Program	Percent Savings or (Loss) Due to Competition	Annual Average Capacity Utilization During Dual-Source Phase
TOW	26.0	63.5
Rockeye Bomb	25.5	70.9
Bullpup AGM-12B	18.7	76.2
Shillelagh Missile	(4.7)	87.0
Sparrow AIM-7F	(25.0)	81.6
MK-46 Torpedo	(30.9)	91.6
Sidewinder AIM-9D/G	(71.3)	82.3

The major problem with the study by Greer and Liao is the forecasting of capacity utilization. For example, they forecasted capacity-utilization data for the seven systems they examined and, using their predictive model decision rules, made the wrong decision in three of seven cases. In other words, they applied their model to the seven systems outlined in table 3-5 and predicted an outcome different from what actually happened in three of seven cases.

They also found that returns earned by contractors on DOD business are measurably lower than the returns on commercial business during periods of low-capacity utilization. Moreover, they concluded that competition produces greater savings when firms are "hungry." They concluded that dual-sourcing is of little benefit as a cost reducer when industry is very active.

Beltramo 84

Beltramo prepared a follow-on paper from his 1982 effort (SAI 82).[21] In it, he drew a distinction between procurements with winner-take-all awards and competitive split-buy awards. He presented tne data in table 3-6 for winner-take-all awards, calculating savings using his three cases discussed earlier. Table 3-7 presents data regarding competitive split-buy awards.

Table 3-6 shows that when winner-take-all competitions are used, the majority of the samples show savings regardless of which case method is used for calculation. In contrast, as shown in table 3-7, four of the seven cases show a loss.

Table 3-6
Selected Cost/Quantity Data for Winner-Take-All Competitions

System	Total Quantity	Cumulative Average Cost ($FY72)	Percent Savings or (Added Costs): First Lot Completed	Total Program	%Savings/ %Completed
MMK48 Torpedo (Warhead)*	1,032	9,717	54.3	23.7	50.9
MK48 (electric assembly)	1,034	12,603	37.5	11.6	24.9
Standard Missile	5,927	51,999	(13.6)	(2.4)	(2.9)
Hawk Missile (Motor Parts)*	14,498	1,534	33.4	19.9	46.7
TD-660 Multiplexer*	3,593	9,141	35.4	14.2	35.9
AN/GRC-103 Radio Relay	963	28,863	59.1	11.9	53.8
APX-72 Airborne Transponder**	27,529	3,014	32.5	9.4 or (1.6)	24.8 or (3.1)
SPA-25 Radar Indicator*	2,011	8,919	25.3	14.2	75.1
TD-352 Multiplexer	3,741	7,399	58.1	36.0	58.0
TD-204 Cable Combiner*	8,733	3,430	56.2	35.5	51.2
CV-1548 Converter	11,583	3,088	63.9	40.2	61.0
TD-202 Radio Combiner*	3,692	3,258	58.1	36.5	51.1
Aerno 60-6042 Elec. Cont. Amp.	666	7,326	53.2	8.5	43.1
MD-522 Modular-Demod.	4,805	3,112	61.4	25.9	55.0
AN/PRC-77 Manpack Radio	143,347	708	32.2	25.2	29.2
FGC-20 Teletype Set ***	1,980	2,091	32.6	4.0	28.8
Aerno 42-2028 Generator	1,679	645	10.7	7.3	19.0
Aerno 42-0750 Voltage Reg.	2,175	110	48.6	29.9	58.1
Average			41.1	19.5	42.6

*Last sole-source buy significantly below learning curve slope.

**Commonly between 7859 and 7859A is at issue: If common, total savings; if not, total loss.

***Last sole-source buy significantly above learning curve slope.

Table 3-7
Selected Cost/Quantity Data for Competitive Split-Buys

Item	Competitive Split-Buy % Savings or (Cost)*	Cumulative Average Cost $FY 72 (000)	Procurement Quantities: Initial Source Pre-Competition	Procurement Quantities: Second Source Education	Procurement Quantities: Competitive Split-Buy	Procurement Quantities: Winner-Take-All	Total
Bullpup Missile G&C	25.8	7.6	10,895	0	30,575	3,580	45,050
TOW	22.6	5.6	18,250	2,885	10,500	78,472	110,107
Rockeye Bomb	3.7	4.3	53,913	0	72,558	0	126,471
Shillelagh Missile	(6.3)	7.1	17,945	4,960	29,386	35,903	88,194
Sparrow AIM-7F G&C	(20.5)	46.7	1,805	295	7,124	0	9,224
Sidewinder	(22.0)	3.8	425	0	2,770	6,760	9,995
MK46 Torpedo Airframe & G&C	(36.4)	28.9	1,650	0	7,298	3,198	12,146

*Actual competitive split-buy costs divided by extrapolation of initial sole-source learning curve for competitive split-buy quantity.

Using these previously calculated data, Beltramo concluded that competitive split buys have resulted in both higher and lower recurring production costs than would be incurred by sole-source producers. He also stated that winner-take-all competitions should be held whenever possible.

Discussion

The first part of the chapter discussed the more prominent studies completed on the impacts of dual-sourcing weapons systems in production. Very little new data have been developed by these studies since the 45 systems analyzed in previous studies were reanalyzed in the TASC 79 report. The balance of this chapter compares the conclusions reached in each of the studies. It also critiques their predictive models for use by DOD in dual-sourcing decisions by examining the elements of cost impact that each study considered.

Elements Considered

Table 3-8 arrays the elements of cost and benefits identified in chapter 2 as potentially impacting on the net cost (added costs minus benefits) accruing to the government by dual-sourcing weapons in production. It also identifies the studies discussed above and the elements that each study considered in its analysis.

The studies have become more comprehensive in the elements they consider and have contributed to our knowledge about dual-sourcing. However, none of the studies has considered all of the potential dual-sourcing costs and benefits. Most studies have explicitly considered recurring production costs and, to a limited extent, have considered nonrecurring production costs where data were readily available.

However, they have seldom identified impacts on the other weapon system program stages. Any benefits accruing to the government during spare parts acquisition due to nonavailability of technical data were not addressed. Additionally, no study identified the impact on other programs that a change in overhead rates would have because of the altered allocation bases in the prime and second sources.

The other major area where costs were omitted were those incurred directly by the government. These include source selection, second-source development, program management costs, extra contract administration costs, and the extra costs associated with configuration management.

Perhaps the biggest omission from all studies that claimed savings was that the time value of money was not considered--the out-year savings were not discounted to a common base-year. This omission precludes any accurate assessment of what the "true" cost or savings is to the government when the decision to dual-source is made for cost-reduction purposes.

Table 3-3

Elements Considered by Study

	ECOM 72	YUSPEH 73	IDA 74	APRO 78	IDA 79	TASC 79	TASC 81	SAI 82
Quantifiable								
Nonrecurring								
Second-Source Selection	N	N	N	N	N	N	N	N
Second-Source Development								
Technical Data Pkg								
Purchase	N	N	N	N	N	N	N	Y
Validation	N	N	N	N	N	N	N	Y
Special Tooling	N	N	N	N	N	N	N	Y
Special Test Equip	N	N	N	N	N	N	N	Y
Tech Transfer								
Leader-Follower	N	N	N	Some	N	N	N	Y
Education Buys	N	N	N	N	N	N	N	
Govt Monitoring	N	N	N	N	N	N	N	N
First Article	N	N	N	N	N	N	N	Y
Contingent Liabilities	N	N	N	N	N	N	N	N
Recurring								
Cost/Quantity Relationship								
Production Rate	N	N	N	N	N	N	Y	N
Learning	N	N	Y	Y	Y	Y	Y	Y
Contract Administration	N	N	N	N	N	N	N	N
Configuration Mgt	N	N	N	N	N	N	N	N
Other Costs								
Company-Funded R&D	N	N	N	N	N	N	N	N
Spare Parts	N	N	N	N	N	N	N	N
Overhead Impact	N	N	N	N	N	N	N	N
Logistics	N	N	N	N	N	N	N	N
Profit	N	N	N	N	N	N	N	N
Nonquantifiable								
Productivity	N	N	N	N	N	N	N	N
Product Quality	N	N	N	N	N	N	N	N
Cooperation								
Technical Transfer	N	N	N	N	N	N	N	N
Ongoing	N	N	N	N	N	N	N	N
Time Delays	N	N	N	N	N	N	N	N
Claims	N	N	N	N	N	N	N	N
Statistical								
Inflation Adjust	N	Y	Y	Y	Y	Y	Y	Y
Discounting	N	N	N	N	N	N	N	N

N=NO Y=YES

Savings Percentages

Table 3-9 arrays by category of system and program the results of data analysis and reanalysis by each study relating to the cost and benefit factors that were considered.[22] Two conclusions can be drawn from a perusal of the data. First, within a specific study there is a range of different savings or losses across programs. Second, the studies reach different conclusions on the impact of dual-sourcing, both in the analysis of the same weapon system and the average program savings calculated by each study.

Results Within Studies

The pattern of savings estimates within any of the studies shows a wide range of savings. This pattern persists when all systems estimates contained in the study are arrayed. More revealing, however, is that when similiar systems such as missiles or electronics are grouped, this same range of estimates persists.

Another problem is that means are unweighted means that can be misleading when comparing systems of widely differing costs. As an example, with unweighted averages, a 5 percent savings on a $1 item is weighted the same as a 5 percent loss on a $1,000 item. On the average, these two impacts result in no average change, even though the monetary impact is obvious. Also, an examination of the mean in relation to the median shows that the underlying distribution of values in each group can differ. With the median to the left of the mean, the distribution is skewed right. If the median rests to the right of the mean, the distribution is skewed left.

Finally, as discussed in the preceding section, these figures do not represent the net impact to the government of dual-sourcing. Taken together, these concerns cast a shadow of caution on the use of any rule-of-thumb estimate of, for example, a 10-percent, 25-percent or other fixed-percentage savings available when systems are competed.

Results Between Studies.

Analysis of the same procurement by different analysts has resulted in different estimates of impacts. In some instances, as in the case of the Shillelagh, some analysts attribute a savings while others attribute a loss. These differences occur because different methodologies are employed and different elements of cost and benefits are evaluated. And they show that there is room for argument among competent analysts over the impact of dual-sourcing on competed programs.

The differences can occur because different studies use different indices or base-years to adjust data for inflation. For example, adjusting contract data to constant-year dollars using the consumer price index instead of the wholesale price index could lead to different

Table 3-9
Estimated Percentage Savings or (Loss)
Due to Competition

	FCOM 72	YUSPEH 73	IDA 74	APRO 78	IDA 79	TASC 79	SAI 84
Missiles & Missile Components							
TOW			48.1	8.5	8.9	12.3	22.6
DRAGON Round				2.7		2.8	
SHILLELAGH		68	(0.2)	5.9	(8.0)	9.4	(6.3)
TALOS (G&C unit)		42	42.3		40.8	39.8	
BULLPUP 12 (Martin)		25	13.9		31.7	26.5	25.8
SIDEWINDER AIM-9D/G					(4.6)	0.7	(22.0)
SIDEWINDER AIM-9B					1.6	(5.6)	
Standard Missile MR RIM 66A		60			(4.2)	59.2	(2.9)
Standard Missile ER RIM 67A		59				34.0	
HAWK Motor Parts		50	6.4		45.7	49.9	46.7
TOW Launcher				30.2	44.2	30.2	
DRAGON Tracker				12.0		12.3	
SPARROW AIM-7F (G&C Unit)						16.0	(20.5)
MEAN		50.7	26.0	11.9	17.3	22.6	6.2
MEDIAN		54.5	13.9	8.5	8.9	19.4	2.9
Torpedos & Bombs							
MK-48 Warhead		54	53.2			48.6	50.9
MK-48 Electric Assembly		55	37.5			47.0	24.9
MK-48 Exploder		80				61.2	
MK-48 Test Set		79				61.8	
Rockeye Bomb		19			(23.0)	(4.5)	3.7
MK-46 Airframe & G&C							(36.4)
MEAN		57.4	45.3		(23.0)	42.8	10.8
MEDIAN		55	45.4		(23.0)	48.6	14.3
Electronic Components							
FAAR Radar				16.6		16.6	
FAAR TADDS				18.2		18.2	
AN/ARC-131				(2.1)		(16.2)	
UPM-98 Test Set	44			3.0		11.5	
PP-4763/GRC Power Sup	58			.3		.5	
TD-204 Cable Combiner		50	50.2		62.1	42.9	51.2
TD-202 Radio Combiner		31	52.5		46.8	40.2	51.1
TD-352 Multiplexer		58	57.8		58.0	55.6	58
TD-660 Multiplexer		41	30.2		38.3	28.4	35.9
60-6402 Elec Control		56	57.0		49.4	52.7	
SPA-66 Radar Indicator		16				(3.4)	
APX72 Airborne Transponder		40	32.6		27.1	23.3	*28.4 or (3.1)
AN/ARC-54	75				55.0	63.1	
AN/PRC-77	48			34.8	20.5	41.9	29.2
AN/GRC-106	54				43.3	41.8	
AN/GRC-103	59				58.7	60.1	53.8
AN/APM-123	67				61.2	67.7	
SPA-25 Radar Indicator			21.3		48.8	10.7	75.1
USM-181 Test Set			36.0		56.0	36.3	
FGC-20 Teletype			32.0		23.7	39.9	28.8
MD-522 Mod/Demod	57		60.3		58.6	51.9	55.0
CV-1548 Signal Conv	59		53.7		64.0	45.4	61.0
AN/ARA-63 Radio		63				57.9	
AN/SQS-23 208A T nsd		47				32.3	
AN/PRL-25						55.0	
AN/ASN-43	12					10.7	
AN/FYC-8X						43.2	
MK-980/PPS-5	65				56.0	66.5	
PRT-4	41				42.3		
Aerno 42-0750					54.8		58.1
Aerno 42-2028					19.9		19.0
MEAN	53.3	44.7	43.9	11.8	47.2	35.5	44.1
MEDIAN	57.5	47	50.2	9.8	52.1	41	51.2
TOTAL MEAN	53.3	49.7	38.0	11.8	33.5	32.9	27.5
TOTAL MEDIAN	57.5	52	39.9	8.5	43.8	39.8	29.0

* Commonality between 7859 and 7859A is at issue: if common, total savings; if not, total loss.

results to the extent the indexes are different. Other differences can originate through use of different estimating techniques or data bases. Finally the differing savings calculations as discussed in chapter 2 can lead to different results, *ceteris paribus*.

Critiques

Several published studies critique these studies in detail. They have been done by such consulting organizations as the Institute for Defense Analysis, Science Applications Incorporated, RAND, and the Logistics Management Institute.

IDA 79. The IDA 79 report discussed earlier reviewed the ECOM 72, IDA 74, and APRO 78 studies.[23] Its major concern with ECOM 72 was the failure to fit progress curves to the sole-source production lots prior to computing savings. IDA 79 fit progress curves to the ECOM data and identified savings of 53 percent vice the 56 percent identified by ECOM. It concluded that the systems selected by ECOM were exceptionally good candidates for the introduction of competition.

Concerns with the IDA 74 study related to its failure to separate nonrecurring from recurring costs and to the fact that the sample could not be considered representative because almost all systems were formally advertised with more than two bidders. It stated that the APRO 78 study was the most sophisticated and well developed methodology for estimating savings. However, it felt that extreme data manipulation and extrapolation were required because APRO, due to a lack of sufficiently reliable data, extrapolated progress curves to ten or more times the sole-source quantities to which they were fitted. IDA 79 was also concerned about the impact that actual or imminent price competition had on sole-source price. And it expressed concern about calculating savings as a percentage of the total program rather than post-competition production. It believed that this method understates the savings to be expected on future competitive unit production costs.

IDA pointed out the sensitivity of savings estimates to different methods of estimating progress curves and the inclusion of different cost impacts. Table 3-10 reflects their analysis of APRO data and how including different elements and using different methodologies for calculating savings can change savings estimates.[24]

Percentage savings for each system as estimated by APRO are presented in column one of the table. The estimates in column two and column three follow the APRO methodology insofar as available fixed costs were used to determine savings and savings were expressed as a percentage of total program costs. However, the learning curve used to make the projections of the sole-source production costs for the estimates in column two were fitted with a weighted regression method. Instead of treating each production lot equally, as was done for the regression curve used in column one, the production lots were weighted in proportion to the size of the lots. Column three learning curves

Table 3-10

Different Estimates of Percent Savings
In APRO Sample

System	Overall Program—All Costs: APRO Unweighted Regression	Overall Program—All Costs: Weighted Regression	Overall Program—All Costs: Cumulative Average Learning Curve	All Costs Competition Production Recurring Costs Only	Single Source Buy Recurring Costs Only	First Competitive Buy [illegible] Recurring Costs Only	First Competitive Buy As Calculated In the [illegible] Study
[illegible] Missile	[illegible][a]	[illegible][b]	[illegible][b]	33[a] [illegible] 33.33	[illegible] [illegible]	[illegible] 47.96	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	None	[illegible]	
[illegible]	[illegible]			[illegible]	[illegible]	39.[illegible]	
[illegible]	[illegible]			[illegible]	[illegible]	59.[illegible]	
Standard Missile	[illegible]	[illegible]	[illegible]	[illegible]	None	[illegible]	
Sidewinder Missile							
AIM 9B	-4.06	[illegible]	-0.23	[illegible]	-29.34	-14.40	
AIM 9D/G	-2.7	+14.34	-7.8	[illegible]	31.54	39.51	
Bullpup Missile	16.[illegible]	14.21	20.2	26.[illegible]	37.62	58.24	13.9 [illegible] 45.8 [illegible]
[illegible] Missile	-21.4[e] -31.63	[e] -31.82	[e]	[e]	[illegible]	[e]	
[illegible] Missile	[illegible]			[illegible]	53.0	None	
[illegible] Missile	[illegible] -4.[illegible]	[illegible]	-3.3	[illegible]	[illegible] -4.[illegible]	[illegible]	[illegible]
[illegible] Radar	[illegible]	[illegible]		[illegible]	None	39.46	
[illegible]	[illegible]	[illegible]		[illegible]	None	[illegible]	
[illegible] Radio	34	[illegible]	[illegible]	[illegible]	None	[illegible]	
[illegible] Radio	[illegible]	[illegible]		[illegible]	None	[illegible]	
[illegible] Test Set	[illegible]			[illegible]	None	[illegible]	

[a]APRO disaggregated the costs into prime contractor costs and subcontractor costs and then estimated two separate progress curves to make the projections used to estimate savings. [illegible] 95 percent progress curve [illegible] was imposed on the subcontractor costs.

[b]The progress curve was fitted to the sum of the prime and subcontractor costs. [illegible]

[illegible]

[illegible] data

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

were estimated by using cumulative average price rather than average price of each production lot as the dependent variable. The progress curves for columns two and three were estimated using only available data on sole-source production lots. However, APRO used something other than sole-source production lots for 10 of the 18 systems analyzed.

For columns four through six, the progress curve as provided by APRO was used to derive the estimates except as specified otherwise in footnotes for the TOW missile. The actual fixed-costs incurred in introducing competition were neglected in calculating the estimates in these three columns; savings were calculated for recurring production costs only. Savings for each system were estimated for all post-competition production in column four; the first split-buy competition awards in column five; and the first competitive buy-out award in column six. Finally, the estimates of savings on the first competitive buy as reported in IDA 74 are given in column seven for systems included in both sides.

In referring to the APRO predictive model, IDA concluded that the two explanatory variables, projected price and ratio of post-competition quantity to total program quantity, are insufficient to predict accurately the actual savings resulting from introducing competition. It concludes with the general assessment that these models

> are insufficient for determining government policy. . . . We are forced to make inferences about the potential impact of introducing competition . . . on the basis of a sample which cannot be regarded as random and representative . . . . The estimated savings for any particular system is therefore subject to considerable error.[25]

RAND 81. RAND conducted a 1981 study for the Office of the Under Secretary of Defense for Research and Engineering.[26] It reviewed four studies: ECOM 72, IDA 74, APRO 78, and IDA 79. It stated that

> these studies contribute to our understanding of the competitive reprocurement process, but they do not (with the possible exception of electronic items) provide convincing evidence of savings due to competitive reprocurement, nor do they provide reliable quantitative tools for decision-making.[27]

The study highlighted the fact that savings estimates made by different analysts on a single system often vary considerably as in the case of Shillelagh which could range from 79 percent to -14 percent.[28] It also pointed out that there is even disagreement in the rank-orderings of savings by program as shown in table 3-11. RAND 81 stated that the major difference between APRO and IDA 79 was that the former used unit production costs and the latter cumulative average prices, and it expressed concern that neither used discounting in their calculations. It concluded that the existing body of analysis has not provided an adequate set of management tools for estimating either the benefits or the costs of competitive reprocurement. It also

Table 3-11
Rank Ordering by Post-Competition Gross Savings Reported by APRO 78 and IDA 79 on Items Included in Both Samples

Item	APRO Rank Within Subset	IDA79 Rank Within Subset	APRO78 Gross Savings ($ thousands	IDA79 Gross Savings ($ thousands
PRC-77 Radio	1	3	41.9	20.5
TOW Launcher	2	1	34.7	44.2
Bullpup AGM-12B Missile	3	2	26.9	31.7
TOW Missile	4	4	12.4	8.9
Shillelagh Missile	5	8	9.4	-8.0
Sidewinder AIM-9D/G GCG	6	7	.7	-4.6
Standard Missile	7	6	-5.4	-4.2
Sidewinder AIM-9B GCG	8	5	-5.5	1.6
Mark 46 Torpedo	9	9	-29.4	-23.0

concluded that it would "be an understatement to say that the determinants of post-competitive price differences have not yet been identified; we were unable to discover a relatively complete list of even the potential determinants."[29] Finally it concluded that it would be difficult to make inferences from the data since the sample could not be construed as representative.

SAI. Beltramo and Jordan performed a review of dual-source competition studies for Headquarters, Naval Material Command.[30] They observed that much of the planning and cost estimating currently being done for systems where competition is contemplated are not based upon sound economic theory or supported by meaningful empirical research.

In critiquing the TASC methodology, one concern SAI had was that TASC eliminates early sole-source buys and thus projects its sole-source learning curve from few data points. They reanalyzed data from the Sparrow AIM 7F guidance and control components which account for about 90 percent of the missile's cost. Projected sole-source learning curves were estimated using three cases:

a. Average first unit cost for three Raytheon buys prior to competition equals 75.3 percent curve.

b. Average first unit cost first for three Raytheon buys prior to competition (to show effect of leaving off first buy) equals 74.1 percent.

c. Cumulative average costs for four Raytheon buys prior to competition equals 76.2 percent.

Beltramo and Jordan calculated the effects of competition, as shown on table 3-3, for the three cases as discussed earlier in the chapter. They concluded that, depending on the case chosen, there was an increase in cost of from 20.5 to 27.5 percent over the estimated sole-source cost, including nonrecurring costs. This is in contrast to a 16 percent projected savings by TASC.

They reviewed three reports and attempted to identify the source of "misinformation" about the AIM-7F saving government money. They concluded that the TASC analysis was accomplished through a misuse of data. First, they asserted that TASC omitted the first and last data points which "can introduce significant errors into projections and naturally enhances the chances of finding shifts and rotations."[31] They also noted the misuse of data by TASC to prove a point such as including the AIM 9-B Sidewinder in the analysis when it had only one sole-source buy prior to competition and thus it was impossible to establish sole-source cost. They also pointed out that the AIM-9D/G, which increased cost by 74.5 percent, was omitted by TASC as were Mark 46 torpedo and Shillelagh missile, which also increased government costs. They concluded by saying that TASC analysis has three critical problems which erode any confidence one might place in its findings:

1) Only competitive procurements which apparently resulted in cost savings were included. 2) Important data which are essential for objectively analyzing the effects of competition were omitted from the systems considered. 3) Although the report enthusiastically supports dual source competition in the procurement of weapon systems, the logical conclusion drawn from the analyses it provides does not support competition.[32]

LMI 82. Yet another review of dual-sourcing studies was accomplished by the Logistics Management Institute (LMI) for the deputy under secretary of defense for research and engineering (acquisition management).[33] In this study LMI made the following conclusion after reviewing the ECOM, IDA, and APRO studies:

> Attempts to use prior evidence of savings achieved from competitive reprocurements to guide future competitive decisions are only appropriate when such evidence is adjusted for the characteristics that influence the level of savings achieved. In most instances, absence of adequate data precludes such an evaluation.[34]

Sherbrooke 83. A study was completed for Headquarters, Naval Material Command by Sherbrooke and Associates in 1983.[35] Their work critiques the ECOM, APRO, IDA, and TASC studies as well as an OSD model.[36] Their concern with the ECOM study was similar to others in that there was no inflation or rate adjustments, nonrecurring costs were not considered, and learning was not projected. They believe that the IDA studies fall short for the same reasons.

They believe that the APRO studies present a more reasoned approach since estimates of parameters for first-unit cost and learning-curve slope are estimated from data and not from regression equations. For example, Shillelagh cost data was used to develop estimates for first-unit cost and slope, which provided accurate estimates. If aggregate data had been used, according to Sherbrooke, a much steeper slope that would have been obtained that would have illogically reflected some nonrecurring costs. They also felt that competition savings were overstated as no production rate was included in the study. Also, they did not favor APRO calculating savings percentages over total program production quantity.

As with SAI, Sherbrooke researchers were disenchanted with the TASC model. They believe that there is substantial reason for skepticism, noting the illogical conceptual framework and the less than rigorous statistical work behind the parameters estimates.[37]

They criticized TASC for not publishing its basis for deflation and pointed out that this can create uncertainty. For example, they showed

that the 1979 price used by TASC was 56 percent of the 1975 price for the leader on the Sparrow program instead of the 50 percent as estimated by TASC. When these revised data are used in a reanalysis, the procurement does not appear to have produced savings, a conclusion also reached by SAI.

The primary Sherbrooke concern is that TASC is trying to estimate too many parameters from too little data. Specifically it could simultaneously be trying to estimate as many as five parameters: first-unit cost, pre- and post-competition learning curve rates, production rate parameter, and optimal production rate from only five to seven years of data.

After these general comments, Sherbrooke examines specific missile programs and identifies individual problems. Reanalysis of the Sparrow program, for example showed the following:

	TASC	ReAnalysis	t
First-Unit Cost:	415,336	426,548	(135.5)
Noncompetitive Cost Improvement Curve Parameter:	.846	.831	(21.9)
Competitive Cost Improvement Curve Parameter:	.777	.824	(31.5)
Production Curve Parameter:	.985	N.S.	--

The reanalysis shows that the competitive cost improvement parameter flattens out more than that calculated by TASC (with almost no change) and that the production rate parameter is not significant. In contrast to the TASC analysis which stated it could not identify the statistical significance of its results, the Sherbrooke analysis was significant at the 95 percent level.[38] Similar results were shown for General Dynamics:

General Dynamics	TASC	Reanalysis	t
First-Unit Cost:	450,186	437,171	(31.9)
Noncompetitive Cost Improvement Curve Parameter	.874	.803	(3.3)
Competitive Cost Improvement Curve Parameter:	.759	.803	(5.2)
Production Rate Curve Parameter:	.923	N.S	-

Analysis was attempted with the Bullpup, TOW and Sidewinder data. The Bullpup had the same results as did Sparrow, and Sherbrooke felt too little data existed to accomplish TOW or Sidewinder AIM-9B analysis.

They recommended that the TASC approach be dropped entirely, both as a research tool for considering past programs and as an ex ante model supporting decision makers.[39] In its place, Sherbrooke recommended the use in ex ante analyses of learning curves and rate parameters that are specific to product groups.

Conclusions

There is currently no robust theory for identifying the projected impact of introducing competition in the production stage of the weapons acquisition process. The models have become more comprehensive over time as the data have been repeatedly reanalyzed. Moreover, the more recent research has attempted to reach beyond contract data and identify explanatory variables for savings estimates. Beltramo considers the method of competition--whether buy-out or split award--as being that variable. Greer and Liao identify contractor "hungriness"--measured by capacity utilization in the aerospace industry--as being the key predictor of savings. However, both studies rely on estimates of savings or loss that have little statistical validity for the reasons already delineated.

An analytical model to describe pricing[40] by contractors dealing with the government ought to consider (1) the technology involved in producing a given item, (2) the markets for the firms' inputs, and (3) the business and final product marketing climate in which the firm operates. A robust pricing theory would have to identify changes in these aspects over time to be able to account for changes in price over time. Beltramo, and Greer and Liao attempt to focus on the third aspect without adjusting data over time to account for the first two aspects.

Any model that accurately describes the defense procurement process over time would have many more variables arranged in a system of interactive equations than are normally included in such a study. Simpler models suffer both from omitted variable bias and from a related problem--simultaneity bias. Even if an accurate, parsimonious model is developed to account for historical relationships, such models are apt to forecast poorly whenever relationships among the conditions bearing on the procurement vary from those prevailing when the data used to estimate the model were generated.

Let us first consider the paper by TASC. While it provides some useful insights and suggests an innovative solution, the author agrees with other analysts that there are flaws in the model that seem to counterindicate an uncritical forecasting application. Certainly the model does not perform as well as the paper claims. We find shortcomings in the general theory, in the data, and in the statistical method. And the researchers have omitted from the studies the details necessary to evaluate the work more completely.

As previously discussed, the TASC research consists of three models. The first is a basic learning curve model, or in TASC's terminology, a "cost improvement curve" model. The unit-cost expression is conventional:

$$Y = AQ^{B},$$

Where:

Y = unit cost

Q = cumulative production

A = first-unit cost

B = parameter

The second model is an extension of the cost-improvement curve model with the addition of a term to capture the effects of changes in production rate. This provision, based on the expectation that the region of decreasing costs covers most defense industry production, makes the TASC Rate Analysis Curve model:

$$Y = AQ^{B}R^{C}$$

Where:

Y, Q, A = as above

R = production rate

B, C = parameters

Production rate measures are not available, so a proxy measure--annual lot size--is used in their stead.

These models are estimated using a nonlinear estimating technique. An empirical example is made using data from the AIM 7 (Sparrow) missile program as reported by SAI. An apparently innovative technique is used to make the regressing equation consistent with the data, which include average lot costs. Unfortunately, that estimating equation is not presented; rather, we are left to infer it. Since the estimating equation is neither linear nor easily linearized, non-linear "curve fitting" techniques are used. Again, we are not told what curve fitting strategy is followed, only that it is effected by means of Newton's method, a procedure for finding approximate solutions by means of successive iterations. Further, there are only eight observations in the SAI data set.

Perhaps the biggest problem with the TASC production rate model is its simplistic form. Ironically, the study goes to some length to establish the problem of omitted variable bias in the simple cost-improvement model. And our discussion of the elements a descriptive/ forecasting model ought to contain should serve to illustrate the extent to which the TASC production rate model is itself subject to ommitted variable bias.

The only estimation results presented were parameter estimates and the sum of squared error terms (SSE), a goodness of fit measure. The study excused the absence of any other statistical information with the remark that nonlinear curve-fitting techniques lacked associated test

statistics. Such nonlinear techniques follow one of two forms: likelihood function maximization or squared-error minimization. TASC used the squared-error minimization technique, which can be tested for statistical significance. Specifically, the likelihood ratio test can be used to test whether, for example, the parameter in equation (2) is different from zero, which in effect tests if there is any benefit to adding the production rate term to the simple cost-improvement model.[41]

Comparison of the SSEs from the cost-improvement model with those from the production rate model reveals a curious fact. The addition of a variable--production rate--to the cost-improvement model yields the production rate model. Therefore, one would expect SSE to go down and Pseudo-R^2 to go up, going from equation (1) to equation (2).[42] This is not the case; the cost improvement model gives a higher Pseudo-R^2 than the production rate model (.995156 to .989044, our calculation), and the cost-improvement model also gives a smaller SSE (6.293E8 to 6.369E8). This may indicate that the algorithm used to implement the optimization routine is not sufficiently powerful to achieve convergence on more complex problems without making search steps larger and coarsening convergence tolerances. This question is largely ignored in the TASC reports, while much is made of the fact that the SSE for fitting total lot cost is improved. The SSE for total lot cost is not the appropriate indicator for goodness of fit; average lot cost is the measure fitted by the equation. We can find the estimated total lot cost by multiplying estimated average lot cost for a given lot by the number of units produced in that lot. The better fit, measured by SSE, of total lot cost is a coincidence, due to the fact that the larger model fits average costs better for the later, larger lots. This is to be expected, since production has become more routine by the time the later lots are produced.

The third model presented in the TASC paper incorporates into the production rate model consideration of whether or not a given lot is procured under dual-sourcing. The technique used is to incorporate a dummy variable to "shift and rotate" the cost-improvement curve. The specific form is:

$$Y = a\,[\exp(d \cdot DC)]\,Q^{(b+fDC)}R^{c}$$

where DC is a binary with a value of one when the lot is procured under competition and zero otherwise. From a curve-fitting perspective, this is a reasonably artful use of dummy variables.

This extended model is then fitted using both the SAI data and data supplied by the AIM-7 program office. These latter data are described in the report as more reliable than those published by SAI. The question naturally arises as to why the SAI data were used in the first place. Why weren't all the models fitted using the superior data? Further, the program office data values average about 50 percent smaller than the corresponding values in the SAI set. Clearly, some different variable definition is involved, but there is no discussion of this fact or what lies behind it.

The first four production lots of the AIM-7 were produced under sole source arrangements, and then were procured in 1977-1979 (1980 in the SAI set) under the split-buy arrangement. In effect, the shift and rotation parameters are fitted to only three observations, using the program office data. Since overall the model is fitted from trended data in five total parameters for seven observations, it is not surprising that the fit is quite good and that the last three observations are estimated with almost no error. This virtually ensures a small SSE in total lot cost. In addition, the very small data set makes the strong claims TASC advances for this model appear exaggerated.

Finally, the construct of the "best competitive curve" in chapter 4 of the paper seems questionable. The model specifies that the original source's learning curve both shifts and rotates with the introduction of competition. As drawn in figure 3-2 on page 52, the post-competition portion of the original source's learning curve is steeper than the "best competitive curve." The accompanying description suggests that this must always be so. According to the model, if competition were introduced from the onset, it would both shift and rotate the learning curve downward to a locus everywhere below the post competition learning curve shown in the figure. We doubt the usefulness of the latter as a predictive tool as it might not be possible for the sole-source contractor to shift his costs to always intersect with the best competitive curve.

Greer and Liao offer an alternative approach, incorporating into their model consideration of an important measure of business conditions: capacity utilization. Basically, they argue that an important element in forecasting a contractor's pricing behavior is the percentage of his total productive capacity that is being utilized. When capacity utilization is low, firms are "hungry" and likely to respond to competitive pressure with lower bids than otherwise. Since capacity utilization rate data are not available for individual firms, Greer and Liao use the average rate of capacity utilization for the appropriate sector of industry as a proxy. While capacity utilization is an important consideration, there are both statistical and theoretic shortcomings in their paper.

As part of the tangential argument to support the contention that excessive zeal in government cost-minimization is misplaced, Greer and Liao attempt to show that defense business is characterized both by lower returns on investment and higher risks than is civilian business. Their approach is to regress by ordinary least squares (OLS) two measures of return on investment--profit on sales, and profit on net worth--against the percentage of a firm's business accounted for by the government. (They use government business as a proxy for DOD business.) Their data base is substantial, covering some 25 firms in the aerospace industry for the 20-year period from 1963 to 1982. They run separate regressions for each firm.

The regression of profit measures against the portion of total business done with the government indicates a negative relationship. Possible errors enter the analysis when an attempt is made to analyze risk using this model. The authors project the profitability that each firm could expect both at 0 percent government business and at 100 percent government business. They then choose as measures of riskiness the standard errors of profitability at no government business and they compare the two to assess the relative riskiness of doing business with the government.

We have three criticisms of this procedure. First, the linear extrapolation of the extremes of business composition for firms whose average concentrations of business run in the range of 40-60 percent (according to the authors) seems likely to be inaccurate. Second, standard deviation is an appropriate measure of risk only under special circumstances. For the analysis at hand, however, it may be the best simple measure available. The most serious problem concerns the measure of risk used.

When projecting the profitability (P) associated with a given proportion of government business (GB), using the following model:

$$P = a + b \cdot GB + e$$

where e is a residual, the variance of a forecast for some P_0 depends on, among other things, the difference between the associated GB_0 and the mean of GB in the sample used to fit the regression. Forecasting far from the sample mean, as is the case here, implies a fair amount of inaccuracy. This procedure will bias the calculation of profit variability at business extremes unless the sample mean for each firm is 50 percent government business. We can also state the direction of this bias. If the average portion of government business is less than 50 percent, then the bias will tend to make government business appear more risky than private sector business. Conversely, if government business is greater than 50 percent of the total, the bias will tend to make private business look more risky than government business. Since the authors do not provide either firm or total sample business composition means, we cannot make a specific assessment of the effects on the bias in this case.

The main thrust of the paper involves estimating two alternative pricing models and using the results to argue that success in dual-sourcing (measured in terms of program savings) depends on the amount of excess capacity among affected contractors. While this is plausible, there are some problems with the statistical work and, in particular, with errors in interpreting the results.

Greer and Liao posit the two models that have already been discussed. There is a production rate model similar to that developed in the TASC paper, written as follows:

$$P = aQ^{b}R^{c}$$

and a capacity-utilization model, written:

$$P = aQ^bU^c\exp(dM + fN)$$

Where:

P = unit price

Q = cumulative production

R = production rate

U = percentage of plant capacity utilized in the industry

M = a dummy variable of the value of one if the buy was under split-buy and zero otherwise.

N = dummy variable taking on a value of one if the buy was in the first year after a winner-take-all competition and zero otherwise.

Estimating equation (5) separately on the data for each program gave rather poor results, both for the original system developer and for the second source.[43] However, the authors' statistical methods could perhaps be improved upon. We will cover these matters below in our discussion of their treatment of the capacity-utilization model.

The capacity-utilization model gave results that on the surface appear reasonable, both for the original developing firm and for the second source. And this model form gave better predictive results than did the production rate model. However, there are some statistical issues which are troublesome, though not necessarily fatal to the argument. First, the authors do not provide any of the conventional summary statistics for any of their regression analyses. Since there are many of these, this material could be given in an appendix.

The paper does provide the average and the median parameter values from separate regressions on each project. The mean and median are calculated after eliminating "outliers." It is poor procedure to eliminate an outlier. The definition of an outlier is based on some notion of what are reasonable results coupled with the observed central tendency of all results. The exceptional case often carries more information than the routine--and may be an indication of the inadequacy of theory, for example. The bottom line on eliminating "outliers" is that it leads to a tendency to discard information at variance with our preconceived notions.

There are also more efficient ways to find "average" parameter values. A common practice is to pool the data from all activities one believes can be described by a single model, and estimate a parameter set jointly.[44] This gives more efficient (accurate) estimation of the structural parameters along with a procedure to test whether or not an "average" set of parameters describing these activities is appropriate.

Finally, some of the conclusions argued by Greer and Liao, apparently based on the stated results from their capacity-utilization model, cannot be substained based on those results. Let's consider their fit of the capacity-utilization equation using median parameter values:

$b = -.278$ $\quad\quad$ $d = -.201$

$c = 1.250$ $\quad\quad$ $f = -.854$

On page 4-4 of their paper, the authors argue that competition is necessary to induce a firm to lower its price when it has unused capacity. On page 4-13, they go on to say, "There is no reason to believe prices react to 'hungriness' when the acquisition program is conducted without competition." The model results do not bear out these assertions.

Let us consider two commonly used measures of responsiveness: the partial derivative of price with respect to capacity utilization, and the elasticity of price with respect to capacity utilization. While the first measure is a common mathematical term, the second should be defined. The elasticity of price with respect to capacity utilization, or the percentage change in price accompanying a one percent change in capacity utilization, is:

$$E = \frac{\text{Percentage change in price}}{\text{Percentage change in capacity utilization}}$$

An equivalent definition is

$$E = \frac{\partial P}{\partial U}\frac{U}{P}$$

If we take the partial derivative of price with respect to capacity utilization, we find it to be

$$\frac{\partial P}{\partial U} = c(aQ^bU^{(c-1)}\exp(d\cdot m + f\cdot n)$$

$$= c\,\frac{P}{U}$$

This implies that for <u>any</u> initial capacity-utilization level, and any value of c, the higher the P the greater will be the change in price that accompanies a small, fixed change in capacity utilization. Since both d and f are negative, P will be lower in the presence of competition than in its absence. Hence, we conclude from the model that the change in price generated by a fixed change in capacity utilization is <u>greater</u> in the absence of competition than in its presence.

In the model, the elasticity of price with respect to capacity utilization levels is invariant with respect to whether or not the buy is competed. The elasticity is:

$$E = \frac{\partial P}{\partial U}\frac{U}{P} = c\frac{P}{U}\frac{U}{P} = c$$

And c is a constant. Both these results show that the structure of the capacity-utilization model is not consonant with the authors' remarks about competition being a necessary condition to extract price concessions from contractors having excess capacity.

A numerical illustration may be useful. Suppose a = 1.0 (no value is given, but any positive number will do for the example). Further suppose that Q = 1000 and U = 65 percent. With no competition, P = 27.05. A fall in capacity utilization to 60 percent yields a price of P = 24.47, for a price reduction of 2.58. The arc elasticity of price with respect to capacity utilization is E = 1.25. If we alternatively consider a split-bid competitive buy, with U = 65 percent capacity utilization and cumulative production of Q = 1000, then P = 22.12; and a fall in capacity utilization to U = 60 percent gives P = 20.01, for a price reduction of only 2.11. Again, the arc elasticity of price with respect to capacity utilization is E = 1.25.

Greer and Liao also contend (p. 5.1) that savings or losses in dual-sourcing can largely be explained by capacity utilization, with losses from dual-sourcing occurring at high capacity-utilization levels. Their model contradicts this proposition as well, as can be seen with another numerical illustration. Suppose again that a = 1.0, Q = 1,000, but U = 80 percent. Now suppose a split-buy competition is initiated. The original source's price before competition is P = 35.06. The post-competition price is P = 28.68 for a unit price improvement of 6.38. Suppose that all other figures remain the same, but that the capacity utilization level is U = 60 percent. The noncompetitive price is now P = 24.47. After competition is introduced, the price falls to 20.02, for an improvement of only 4.45. Since in the model the introduction of competition improves price more at higher levels of capacity utilization, we contend that the model contradicts rather than supports the authors' argument.

Greer and Liao's argument has intuitive appeal, but the above discussion points to an ill-designed model. It could be improved to give more sensible responsiveness results by making the exponent on capacity utilization depend on the presence or absence of competition, and by making coefficients on the dummies for the introduction of competition depend on capacity-utilization levels, as follows:

(6a) $P = aQ^{b}U^{(c+c'M+c''N)}\exp(dN+d'N\cdot U+eM+e'M\cdot U)$

Summary

This chapter opened with a discussion of studies that have attempted to quantify the costs and benefits of dual-sourcing. It reviewed their data, methods, and major conclusions. It found that different studies analyzing the same program arrived at different

estimates of savings or increased cost to the government. It also found that no rule-of-thumb exists that points to a fixed percentage savings--such as 25 percent--accruing to the government whenever a weapon system is competed in production.

We identified several reasons why estimates of savings were different between studies:

(1) Different inflation adjustments and data manipulation

(2) Different bases for calculation of savings estimates, such as first calculation of savings competitive buy versus total program

(3) Inclusion of different systems

(4) Specification bias since some calculations net out nonrecurring costs while others report gross savings

None of the studies considered extra costs to the government such as source-selection, contract administration or configuration management costs. Moreover, no study addressed the potentially favorable or unfavorable impacts on other stages of the program such as better spare parts pricing because of the existence of a technical data package, or claims resulting from a poor technical data package. And the majority of systems studied to date have been low dollar value, high quantity systems that were mass produced. To extrapolate the results in a predictive sense to high dollar value low quantity systems should be done very cautiously.

Published critiques of these studies were reviewed. They were unanimous in their conclusions that there is not adequate data, even if there were a methodology, to develop in a predictive sense a statistical procedure to capture the simultaneous equation system necessary to identify the impacts we discussed earlier--factor inputs, markets, and technology. (This conclusion was initially stated in the 1972 ECOM study!) In fact, we showed how at least one study yields results that contradict the assertions claimed by the analysts.

Notwithstanding the shortcomings discussed above, three points must be made. Dual-sourcing of weapons is done for many purposes--to develop surge capability, to advance technological progress, and to foster contractor cooperation among others--not just to reduce weapon systems cost. Therefore, a sample of programs that have been competed cannot be considered a random sample and representative of all procurements such that the results can be extrapolated to other programs, something that has been done at the highest levels of the executive and legislative branches. And a second point which stems from the first is that we do not know when competition leads to reduced cost or profit. If the government is using its leverage in the short run to reduce profit, especially in light of evidence that hints profits on defense business are less than commercial business, we may be benefitting in the short run at the expense of the long-run viability of our defense

industry. The available data that we have at the contract price level (cost plus profit) simply does not allow us to draw these important distinctions. Finally, we must avoid uncritical application of mechanical techniques to forecast future savings from historical data.

Chapter 4 will explore program-specific analyses that have been conducted to help determine the cost effectiveness of dual-sourcing.

NOTES

CHAPTER 3

1. US, Congress, Hearings on Military Posture and H.R. 4016, Hearings Before the Committee on Armed Services, House of Representatives, February-March 1965, 433 and 439.

2. Dr. Jacques S. Gansler, "Getting More for Our Defense Dollars," a prepared statement in testimony before the House Budget Committee, 8 November 1983, 6.

3. The individual studies and the several critiques discuss these major points in-depth. It is my purpose to briefly touch on their major points to help the reader understand the conclusions I have drawn. A complete bibliographic citation is given for the reader who desires a more thorough review of individual studies. Moreover, most of the studies have been summarized elsewhere. See for example George Daly, et al., The Effects of Price Competition on Weapon System Acquisition Costs, IDA Paper P-1435 (Arlington, Va.: Institute for Defense Analysis, 1979); K. A. Archibald, et al., Factors Affecting the Use of Competition in Weapon System Acquisition, Report R-2706-DR&E (Santa Monica: The RAND Corporation, February 1981); Myron S. Myers, et al., Price Competition in the DOD (Washington, D.C.: Logistics Management Institute, September 1982); and Quantitative Acquisition Strategy Models (Potomac, Md.: Sherbrooke and Associates, March 1983).

4. US Department of Defense, US Army Electronics Command, "A Review of the Cost Effects of Sole Source vs Competitive Procurement," by Cost Analysis Division, Comptroller, February 1972.

5. Ibid., 22.

6. Larry Yuspeh, "The General Advantages of Competitive Procurement over Sole Source Negotiation in the Defense Department," a study prepared for the Subcommittee on Priorities and Economy in Government of the Joint Economic Committee, US Congress 12 November 1973.

7. Ibid., 2.

8. Morris Zusman, et al., A Quantitative Examination of Cost Quantity Relationships, Competition During Reprocurement, and Military Versus Commercial Prices for Three Types of Vehicles, Report IDA Paper S-429 (Arlington, Va.: Institute for Defense Analysis, March 1974).

9. Ibid., 59.

10. Edward T. Lovett and Monte G. Norton, Determining and Forecasting Savings from Competing Previously Sole Source Noncompetitive Contracts, Report ARPO 709-03 (Fort Lee, Va.: Army Procurement Research Office, October 1978). The APRO study was

partially accomplished by Tecolote Research Inc., which analyzed 6 of the 16 systems in their report, Arthur J. Kluge and Richard R. Lieberman, Analysis of Competitive Procurements, Report TM-93 (Santa Barbara, Calif.: Tecolote Research Inc., August 1978).

11. Ibid., 36.

12. George G. Daly, The Effect of Price Competition on Weapon System Acquisition Costs, Report P-1435 (Arlington, Va.: Institute for Defense Analysis, September 1979).

13. Ibid., 83.

14. J. W. Dinnon and J. R. Hiller, Predicting the Cost and Benefits of Competitive Production Sources, Report TR-1511 (Arlington, Va.: The Analytic Sciences Corporation, December 1979).

15. Larry Cox, et al., Analysis to Support Evaluation of the Potential Benefits of Competition in Cruise Missile Production, Report TR-3313 (Arlington, Va.: The Analytic Sciences Corporation, December 1979).

16. Ibid., 4-12.

17. Ibid., 4-19.

18. Ibid., 4-21.

19. Michael N. Beltramo and David W. Jordan, A Brief Review of Theory, Analytical Methodology, Data, and Studies Related to Dual Source Competition in the Procurement of Weapon Systems (Los Angeles: Science Applications, Inc., 27 August 1982); Michael N. Beltramo and David W. Jordan, Issues to Be Considered in Establishing Dual Source Competitions (Los Angeles: Science Applications Inc., 24 September 1982); and Michael N. Beltramo, "Some Findings, Theories, and Thoughts about Competition in the Procurement of Weapon Systems," draft of paper to be presented at 18th Annual DOD Cost Analysis Symposium, Washington D.C., 25 June 1984.

20. Willis R. Greer, Jr., and Shu S. Liao, Cost Handbook for Dual-Source Weapons Procurement (Monterey, Calif.: Naval Postgraduate School, October 1983).

21. Michael Beltramo, "Findings, Theories, and Thoughts," draft of paper for presentation at 18th Annual DOD Cost Analysis Symposium, 1984.

22. Adapted from Sherbrooke, Quantitative Models, 25-6. It is virtually impossible to find consistent numbers for estimates even within a given study, as will be discussed shortly. This represents a best estimate to portray the results of the research.

23. Daly, et al., _Price Competition._

24. Ibid., p. 58.

25. Ibid., p. 59-60, H4-5.

26. K. A. Archibald, _Factors._

27. Ibid., 46.

28. This variation was discussed as it related to the IDA calculations. Table 2-5 of this research shows the calculations.

29. Archibald, _Factors_, 52.

30. Beltramo and Jordan, _Brief Theory_; Beltramo and Jordan, _Issues_; and Beltramo, "Findings."

31. Beltramo and Jordan, _Brief Theory_, 25.

32. Ibid., 22.

33. Myron G. Myers, et al., _Price Competition in the DOD_ (Washington, D.C.: Logistics Management Institute, September 1982).

34. Ibid., 3-9.

35. Sherbrooke, _Quantitative Methods._ The lead analyst completing this study was a former TASC employee and had worked on the TASC methodology.

36. J. C. Bemis, "A Model for Examining the Cost Implications of Production Rate," _Concepts_, Spring 1981. This model is based on the TASC model and is not discussed separately in this report.

37. Sherbrooke, _Quantitative Models_, 29.

38. Values of "t" over 2 indicate statistical significance at the 95 percent level.

39. Sherbrooke, _Quantitative Models_, 53.

40. A common error is that analysts fail to make sufficient distinctions between the cost of producing an item, a matter difficult to ascertain with any accuracy, and that item's price.

41. For a description of the likelihood ratio set, see, for example, Lester D. Taylor, _Probability and Mathematical Statistics_ (New York: Harper and Row, 1974), 244-288.

42. Since the model is nonlinear, the conventional R^2 measure is not defined. Pseudo-R^2 is a similar measure, and is the square of the correlation between the fitted values of the dependent variable and the observed values.

43. This casts further doubt on the modeling approach suggested in the TASC paper critiqued above.

44. This procedure, referred to as pooling cross-sectional and time-series data, is described in J. Kmenta, Elements of Econometrics (New York: MacMillan, 1971), 508-517.

CHAPTER 4

PROGRAM SPECIFIC COMPETITION ANALYSES

The weapons acquisition process requires that cost estimates be conducted for a variety of reasons and at a number of levels. Program managers must develop alternative acquisition strategies and cost estimates to evaluate each strategy's effectiveness in completing the acquisition as set out in the program manager's program management plan. In accordance with DOD directives, separate cost analyses must be conducted for major weapons systems as an independent test of the reasonableness of program office estimates.[1] These analyses can be as extensive as a detailed independent cost analysis (ICA) in support of a Defense System Acquisition Review Council (DSARC) decision to approve progression of a weapon system from one acquisition stage to another as discussed in chapter 2. Somewhat less detailed is an independent sufficiency review that consists of a summary review of a program office estimate. Finally, the least detailed cost analysis consists of an independent cost study that reviews program office ground rules and estimating methodologies. Whereas the first two are compared to program office estimates, the latter does not necessarily include an evaluation and a detailed comparison with a program office estimate.

The balance of this chapter outlines selected Army, Navy, and Air Force program office and ICA analysis methodologies for estimating the costs and benefits of dual-sourcing weapons in production. First, however, is a quick review of cost-estimating techniques to set the stage for the remainder of the chapter.

Cost-Estimating Methods

Cost-estimating methods used in making an individual analysis vary widely among analysts. However, three methods of estimating are generally available: analogy, parametric, and the industrial engineering approaches.

Analogy and parametric methods are "top down" approaches because they forecast total program costs as a single number. Analogy estimates are based on data from similar past programs or tasks, with adjustments made for differences in the present program. They generally involve the use of learning curves and their power function adjustments.

Parametric estimates develop a cost-estimating relationship where cost is determined from an estimate of a physical or performance characteristic of the program, such as weight or speed of the system. It can also be based on the number of personnel assigned to a level-of-effort task. One example of a parametric cost-estimating method was developed by RCA. Its Programmed Review of Information for Costing and Evaluation (PRICE) model was developed for estimating engineering development costs of electronic equipment.

The industrial engineering approach is a "bottom's up" estimating technique that estimates each of the cost elements of the program. It is generally the most accurate as it is accomplished after firm designs are known and production technologies established. This technique can also use learning curves for individual labor elements.

Although these methods are discussed as discrete methods, they are not used independently. The engineering approach, for example, can utilize analogy or cost estimating relationships to estimate the individual cost elements.

Program Analyses

The military services and OSD all have conducted program specific competition analyses. We will now examine selected program specific studies, reviewing the factors considered in the analysis (as identified in chapter 2), methods of analysis, and statistical treatment of data.

IIR Maverick

The IIR Maverick is an imaging infrared guided missile designed to target tanks, bunkers and other ground targets. The missile was designed by Hughes Aircraft Company and has two major sections--the imaging infrared guidance and control section (GCS) and the center/aft section (CAS). The GCS is unique to this system, while the CAS is common to TV, laser and IIR Mavericks.

Production of the IIR Maverick began in FY 82 with 200 missiles. Current planning includes the production of 500 units in FY 85 with competition starting in FY 86 for the remainder of the 60,664 missile requirement between FY 82 and FY 90.

On 24 November 1982 Headquarters USAF directed that an independent cost analysis of the program be performed. The ICA was completed in February 1983 as an independent test of the reasonableness of the program office estimate.[2] It was developed using three scenarios: (a) a 50/50 split in years 1986 through 1990, (b) a 50/50 split in 1986 with a buy out from one producer for the 1987 and future requirements, and (c) an 80/20 split between Hughes and the second source.

The general methodology was to make a building block estimate of the cost of a Hughes' sole-source buy and reduce the relevant costs to reflect the effects of competition. Methods used to develop the Hughes estimate included the RCA Price-H model, an analogous estimate of the FMS program and IIR production lot, purchase order data, and the TV Maverick cost history among other sources.

The methodology for estimating the effects of competition was based on the model developed by The Analytic Sciences Corporation (TASC), which showed three effects:

fee reduction	4 percent	12% $\pm$ 2%
other overall cost reduction	8 percent	
greater learning	4 percent	

The ICA accepted the TASC numbers and took a 5 percent fee reduction, a 9 percent other overall cost reduction, and a 4 percent greater learning factor against the guidance and control section starting in FY 86. The most optimistic estimate in the uncertainty band estimated by TASC was used. For the center aft section only a 5 percent fee reduction was taken because the component was presently being procured under the TV Maverick program and it was felt that the learning had terminated.

The following results were obtained showing the forecasted sole-source cost and expected cost of the three competitive scenarios in base and then-year (TY) dollars:

	TY Dollars	FY 82 Dollars
	Millions	
50/50 split	5,794	4,003
50/50 FY 86 followed by buy-out	5,461	3,794
80/20 split	5,651	3,911
Sole-source	5,866	4,042

These figures show that if the FY 86 50/50 award is made and is followed by a multiyear buy-out, there would be a savings of 248 million dollars over the projected sole-source cost. This equates to 6 percent of total program cost in FY 82 dollars. As stated, point estimates of the probable cost under the three scenarios were made by applying the most optimistic average percentage reductions to the respective cost elements estimated in the sole-source case. If the ICA had used other than the most optimistic estimates, the lowest price ICA scenario would have been higher and much closer to the SPO estimate of 5,513 million dollars.

In developing its sole-source estimate, the ICA team assumed the second source would be developed and "that after the FY 85 buy of 500 units from the second source, the Air Force decides to abandon the notion of competition (for some unknown reason) and purchases the remaining missiles from Hughes."[3] In addition to the learning curve penalties of having the second source produce the 500 missiles on its learning curve rather than Hughes produce them down its learning curve, the following second-source costs were also included in the sole-source estimate because of this assumption:[4]

	TY $, Millions
tooling	47.35
qualification	87.84
system engineering/program mgt	36.60
TOTAL	171.79

It would have been more appropriate for the ICA team to have excluded these second-source development costs from the sole-source estimate if it was attempting to identify the cost-reduction implications of the competition as stated in its report.[5]

It did not use discounted cash flows, nor did it consider the additional source selection and contract administration costs. Finally, it discussed the impacts on program costs for spares but did not quantify them. Nor did it consider the effects on the price of other government programs such as the TV, FMS, laser, and Navy IIR Maverick programs.

LANTIRN

The Air Force is presently developing the low-altitude infrared navigation and targeting system (LANTIRN) developed by Martin-Marietta Corporation (MMC). The system consists of two externally mounted pods with 720 pod sets programmed for purchase and use on the F-16 and A-10 aircraft for night under-the-weather attack capability.

Congress prohibited the obligation or expenditure of any FY 83 development funds for the targeting pod until there was a competitive demonstration between the LANTIRN targeting pod and the product improved F/A-18 FLIR targeting pod developed by Ford Aerospace. TASC published a report in May 1983 at the request of the LANTIRN program office which outlined possible competitive strategies that would satisfy congressional and Air Force objectives.[6]

The May 1983 submission updated a July 1982 plan which initially developed alternative acquisition strategies and identified potential R & D and procurement costs for LANTIRN. The updated report discussed the competitive fly-off, five leader/follower alternatives, and a component breakout program.

Recurring cost-savings estimates for the competitive fly-off were estimated at 7 percent in then-year dollars. This was considered a reasonable estimate based on a reference to the APRO 78 study discussed earlier. From this figure TASC analysts subtracted additional development and schedule impact (inflation) costs, which resulted in an added cost of 133.5 million in then-year dollars for this option.

The five leader/follower alternatives included combinations using the pods as a set or competitive procurement of only the targeting pod. Alternate I is the targeting pod only with a production rate of 16 per month and competition starting in lot 2 with a multiyear buy-out for the last two buys. Alternative IIa is similar to I except competition starts at lot 3. Alternative IIb is similar to IIa except production is 12 per month. Alternative III(a) involves competition for both pods with production at 16 pods per month and competition starting with lot 3. Alternative III(b) is similar to IIIa except for production of 12 pods per month.

The analysts estimated program costs of the leader/follower acquisition strategies by using TASC's production cost analysis predictive methodology (PCAM) discussed in chapter 3. Use of this model involves estimating the system developer's shift and rotation of the learning curve. In a predictive sense, the model assumes that the system developer alters his cost behavior just enough to stay ahead of the second producer in a competitive environment. This translates into a shift and rotation of the system developer's cost-improvement curve adequate to intersect the best competitive curve at the end of the planned production run. Furthermore, once parity is achieved, if production quantities are extended, the producer continues to follow the best competitive curve. The model calculates the system developer's shift and rotation on the assumption that he bids to win. And it implicitly assumes that he has perfect insight into the second source's cost behavior. It also assumes the second source is always less expensive than the first source.

The calculation of a projected shift for the system developer involves projecting each producer's unit cost up to the point of competition. The difference between the projections establishes the amount the original producer must reduce his cost to win the competition. The general equations required to calculate the required shift and rotation are presented below. They assume that the developer produced N units prior to competition and that the second source produced K units prior to competition.

Cost of Developer N + 1 unit =

$$A(N + 1)^{B} (Y)^{C}$$

Cost of the Second Source K + 1 unit =

$$D(K + 1)^{E} (X)^{F}$$

Developer's Cost Improvement Curve Shift =

$$1 - \frac{D(K + 1)^{E} (X)^{F}}{A(N) + 1)^{B} (Y)^{C}}$$

Where:

A and D represent first-unit costs.

B and E represent the log of cost improvement rate/log of 2.

Y and X represent optimal lot sizes.

C and F represent log of production rate parameter/log of 2 for the developer and second source, respectively.

Calculation of a rotation of the system developer's cost-improvement curve is based upon the cost reduction he must attain to continue to win the competitive awards through the remaining production run. The general form of the equation used to calculate rotations for the LANTIRN system developer and leader is logarithmic:

$$\ln R = \frac{(\ln 2) \ln 1/SM^{a}}{\ln (N + 1)/M}$$

Where:

R is the rotation.

S is the ratio of second source's K+1 unit cost/developer's N+1 unit cost.

M is the number of units produced when the rotated curve meets the best competitive curve.

N+1 is the first competitive unit.

a is the negative logarithm of best competitive rate/developer's rate divided by the ln of 2.

Using this predictive methodology, TASC estimated the costs and benefits in then-year dollars as reflected in table 4.1.[7] No further detail beyond this chart was reported in the analysis.

The TASC analysts concluded that total program cost reductions ranged between $118.9 and $275.2 million in then-year dollars. They included the following caveat with the estimate:

> This update of the LANTIRN Competitive Procurement Plan was a quick reaction re-look at several acquisition strategy alternatives and the results are Rough Order of Magnitude. We recommend that if the Program Office is interested in pursuing any of these options, more analysis should be done. In other words, a thorough analysis of what makes sense as a LANTIRN Acquisition Strategy--a detailed examination of system elements, contract options, data rights, etc., and a carefully constructed cost/benefits analysis must be accomplished prior to structuring a viable acquisition alternative.[8]

Table 4-1
LANTIRN
Leader/Follower (L/F) Alternatives

Potential Savings

Alternatives	System	Production Rate	L/F Savings	L/F Qual Costs	Potential Net Savings
			TY$	TY$	TY$
*I-L/F Only	Target Pod	16/Month	309.8M	176.6M	133.2M
-L/F W/Buy-out	Target Pod	16/Month	402.5M	176.6M	225.9M
*IIa-L/F Only	Target Pod	16/Month	301.0M	182.1M	118.9M
IIb-L/F Only	Target Pod	12/Month	307.8M	168.0M	139.8M
IIIa-L/F Only	Both Pods	16/Month	449.4M	231.5M	217.9M
IIIb-L/F Only	Both Pods	12/Month	501.0M	225.8M	275.2M

* Difference is for Alternative I, competitive split began at lot 2; for Alternative IIa, competitive split began at lot 3.

This analysis projected a downward shift of 20 percent in the learning curve and a rotation to 64 percent from a 92-percent curve. When questioned by the government, the TASC analysts could not reconstruct the analysis. And a subsequent TASC analysis showed a shift of the learning curve of 9 percent and a rotation to 88 percent.[9]

As a result of the TASC report, the program office issued a Cost Alert List (CAL) projecting a savings of $139 million in base-year 1980 dollars and $320 million in then-year dollars. On 8 August 1983 ASD/ACC reevaluated the proposed savings but could not validate them for several reasons. First, they believed data used to compute TASC cost-estimating relationships were obtained from systems procured in large quantities (up to 10 times more) and lower unit cost (15 to over 100 times less expensive) and they stated conclusions from these data could not be extrapolated to LANTIRN. Second, the subsequent TASC analysis reduced the base-year savings estimate to $5 million. Third, TASC reduced the program costs based on decreased systems engineering/program management and data requirements. ASD/AC did not accept these reductions. Fourth, TASC imputed a reduction of 27 percent of recurring hardware savings for reduced general and administrative (G&A) expense and fee. However, the G&A expense and fee in the baseline cost estimates were already included in the recurring cost savings. These adjustments changed the TASC estimate to a net increase in base-year 80 dollars of $38 million.

ASD/AC reestimated competitive savings using methodology similar to that employed on the Aeronautical Systems Division (ASD) IIR Maverick ICA. ASD/ACC projects an additional $106 million (FY 80$) would be required as shown in table 4-2.

Table 4-2
ASD/ACC LANTIRN ICA (720 Units)
(BY80$, Millions)

	With Competition	Without Competition	Savings
Recurring Hardware			
Leader (MMC)	$776		
Follower	250		
Subtotal	$1,026	$1,045	$ 19
Other Costs	704	576	-128
Engineering Change Orders	104	107	3
TOTAL	$1,834	$1,728	$-106 (NET Add)

Neither estimate considered the added costs to the government for selecting the second source, monitoring technical transfer, or administering the additional contracts. They also did not address the potential impact on company-funded R&D, overhead impacts, or the benefits to be gained through competition for required spare parts. In addition, the estimates did not discount cash flows.

AMRAAM

The advanced medium range air-to-air missile (AMRAAM) was developed by the Hughes Aircraft Company. An estimated twenty thousand missiles will be built over the nine-year period ending in 1992. Competition between Hughes and Raytheon was examined as a potential acquisition strategy using the leader/follower technique with three years of directed buys and competition involving four additional lots.

Analysis of the potential impact of program costs under competitive leader/follower procurement was undertaken to study the cost impact of competition on the air vehicle.[10] According to comptroller personnel, the analysis was undertaken in-house because TASC's analysis was not acceptable.[11]

Armament Division (AD) developed a competition interactive computer model that used parameters developed from Sparrow and Sidewinder data to generate total estimated competitive cost for AMRAAM. This was accomplished by an analogous extrapolation to future AMRAAM lots of the Sparrow and Sidewinder data to Hughes proposals for AMRAAM lots I and II. AD felt that this was reasonable since both Sparrow and Sidewinder programs were sole-source procurements followed by competitive procurements. Proposal data for these procurements were available for seven lots, and data were submitted for five different production quantities or step bids within each lot.

The analysis of the proposal data involved four cost elements: material, direct manufacturing labor, manufacturing support labor, and engineering support labor. Noncompetitive and competitive recurring cost trends were identified between production lots and for each bid quantity within a production lot using cost-improvement curve analysis for each cost element. Nonrecurring costs were estimated from AMRAAM program office sole-source estimates.

An analysis of the cost-improvement curves for the submitted step bids for each lot showed that the curves had a range that could reflect (a) contractor competitive bidding strategy, (b) cost improvement, or (c) production rate effects. No attempt was made to separate the individual impact of these variables on the data.

Analysts calculated the competitive cost-improvement curve in two steps. First, they calculated the projected bottom point on the cost-improvement curve for each cost element (where the cost improvement stops) by using the ratio of the cost element's lowest observed cost or hours competitive value to its value at the last noncompetitive procurement:

$$\text{Lowest value percentage} = \frac{\text{lowest observed value}}{\text{value at last non-competitive procurement}}$$

The lowest observed value for Hughes was derived by multiplying this percentage by the cost element's value proposed by Hughes in its last noncompetitive proposal. The competitive improvement curve for the cost element was then derived by projecting what the improvement rate must be to achieve the lowest expected value in the penultimate competitive procurement.

The actual improvement slopes and bottom-out points for the four cost elements were calculated for Sparrow and Sidewinder from historical data. Applying these parameters to the Hughes (AMRAAM) proposal for lots I and II, analysts projected that the estimated recurring costs for the sole-source production of 20,000 missiles at a rate of 2,500 per year would be $2,284.7 million in FY 78 dollars. They estimated that the recurring cost using the leader/follower strategy, tooling each at a capacity of 1,800 per year, would be $2,119.4 million in FY 78 dollars. Nonrecurring costs were taken from SPO estimates as follows:

	FY 78 millions
follower planning	$10.4
Hughes technical transfer	4.0
reprocurement data	12.2
follower qualification program	8.9
tooling and test equipment	49.4
vendor nonrecurring qualification	11.1
TOTAL	$96.0

Finally, analysts developed an estimated cost of $11.8 million for the reduced tooling required due to the production rate of 1,800 per year at both contractors compared to a capacity of 2,500 at Hughes.

Table 4-3 summarizes results of the analysis.[12]

Table 4-3
Summary Cost
FY 78 Millions

	Sole-Source	Leader/Follower
Additional nonrecurring	0	96
Recurring	2,284.7	2,119.4
SPO costs	546.1	546.1-11.8=534.3
TOTAL	2,830.8	2,749.7

Total undiscounted estimated savings was 81.1 million dollars or 2.8 percent of program costs. While the analysis presented the required budget profile by year, it did not discount the differing profiles of the sole-source and competitive situations. Discounting the profile using the 10 percent rate as required by OMB circular A-94 yields an estimated discounted savings of $6.1 million as shown in table 4.4.

Table 4-4
AMRAAM
Summary by Year Funding
(FY 78 millions)

FY	83	84	85	86	87	88	89	90	91	Total
Discount Factor	--	.909	.826	.751	.683	.621	.564	--	.467	
Sole-Source Undiscounted	--	131.1	316.1	423.6	436.7	386.8	678.9	--	457.6	2,380.8
Sole-Source Discounted	--	119.2	261.1	318.1	298.3	240.2	382.9	--	213.7	1,833.4
Leader/Follower Undiscounted	26.6	161.6	321.7	468.7	452.7	370.1	560.4	--	387.9	2,749.7
Leader/Follower Discounted	26.6	146.9	265.7	352.0	309.2	229.8	316.1	--	181.1	1,827.4

1,833.4 - 1,827.4 = 6.1 million discounted savings

This value is obtained by multiplying the undiscounted sole-source and leader/follower figures by th discounting factor, summing the respective products, and subtracting for the difference.[13]

In addition to not discounting the analysis, the AD analysts did not consider the impact of changes on other stages of the acquisition process or on other programs. Moreover, they felt there would be a reduction in SPO costs and did not consider contract administration or additional configuration management costs.

MLRS

The multiple launch rocket system (MLRS) is a free-flight rocket system consisting of a self-propelled loader launcher (SPLL) and two expendable launch pods/containers (LP/C), each of which stores six rockets. The rockets contain a solid propellant motor, fuze, and warhead.

Five companies were awarded contracts for concept definition in 1976, with Boeing and Vought being awarded competitive development contracts in 1977. In 1980 Vought was chosen for final development and awarded contracts for production facilities and four options for low-rate production. These options totaled 28,476 rockets and 4,746 LP/Cs.

MLRS DSARC III guidance directed that the Army consider acquisition strategies to obtain production price competition on the rocket and LP/C and that it consider the impact on price of different total program quantities and production rates. The Army completed its second-source acquisition analysis in December 1980.[14] The study was designed to provide estimates of the optimum procurement strategy for either 190,000 or 360,000 rockets and a break-even point for each strategy.

The study evaluated four competitive options. The technical data package (TDP) option involved obtaining a validated data package from the developer and soliciting from other contractors. The second option involved the leader/follower concept in which technical data is transferred to the second source during development. A third option was labeled the "freedom of design approach" (FOD) in which Boeing would build a LP/C-rocket of its own design but capable of interoperability with Vought's SPLL. The fourth option involved a freedom of design approach in which the second source was provided a copy of Vought's unvalidated TDP and allowed considerable design flexibility in making changes. Production rate options under each strategy involved 2,000, 4,000, and 6,000 units produced per month.

Each combination of procurement strategy, production rate, and production quantity was evaluated under three criteria: program and contractual issues, technical and operational issues, and economic issues. Program and contractual issues involved the quantitative assessment of schedule impacts, configuration management, warranties,

prime contractor cooperation, and the impact on provisions of a memorandum of understanding between participating countries in the procurement. Technical and operational issues included the potential availability of second-source contractors, potential for technological innovation, impact on the fire control system integral to the SPLL, logistic considerations, assessment of technical risk, testing requirements, and TDP validation requirements. Economic issues included analysis of increased nonrecurring and decreased recurring costs calculated as a percentage reduction of projected sole-source cost.

Sole-source cost estimates were based on a first-unit cost of $10,726 (FY 80) for a production rate of 6,000 per month. Reduction in quantity from 360,000 to 190,000 was estimated to cause a 4 percent increase in unit cost due to capital depreciation over the smaller quantity. Reduction in production rate from 6,000 rockets per month increased first-unit cost as follows:

Rate per month	First-unit cost increase
4,000	4%
3,000	10%
2,000	25%

Unit costs were projected to increase by 5 percent after FY 83 to reflect noncompetition in follow-on procurements.

Nonrecurring costs differed between acquisition strategies. Included in the freedom-of-design option were additional research and development, TDP validation, government R&D, and government-furnished equipment and testing. Additionally, all competitive options included projected costs for contractor system and production engineering and program management, prime contractor support to the second source, production qualification testing, and initial production facilities cost. Table 4-5 shows the estimated lower and upper limits for each cost element and acquisition strategy.[15]

Recurring costs were estimated for the following elements in each option: hardware manufacturing, recurring engineering, quality assurance, engineering changes, data, contractor and government system project management, and first destination change.

Hardware manufacturing cost accounted for 65.2 to 79.7 percent of total cost of the options and was given the most attention. Three variables were used to estimate recurring manufacturing cost: theoretical first-unit cost, learning curve slope, and learning curve step functions.

Table 4-5
MLRS Nonrecurring Cost Summary
(FY 80 $M)

Option	2,000/Mo	3,000/Mo	4,000/Mo	6,000/Mo
Sole-Source	20	25	30	38
TDP Traditional	39-57	46-66	52-75	62-89
TDP LDR/FOL	45-68	52-77	58-86	68-100
FOD Designated	94-124	101-130	108-136	118-145
FOD Competitive	106-137	114-146	121-155	131-169

A theoretical first-unit cost of $6,849 (FY 80$) for the MLRS rocket (less submunitions and fuze) and $18,229 for the LP/C were used in the DSARC-approved baseline cost estimate and were accepted by the study team.[16] This estimate was predicated upon a maximum production rate of 6,000 rockets per month and a total production quantity of at least 326,475. As all options did not meet this baseline, first-unit cost was adjusted to reflect changes in production rate and total quantity. Rate adjustments were as follows:

Rocket Rate	Relative Unit Cost
2,000	1.25
3,000	1.10
4,000	1.04
6,000	1.00

Learning curve slope was based on a 91 percent curve for both the prime and second source as developed for the DSARC review. Factors that supported the shallow 91 percent curve were the high degree of automation and the fact that material comprises over 70 percent of total recurring manufacturing cost.

Competitive pressures on recurring cost were treated as learning curve step functions. Four step functions accounted for the initial low production rate change expected for split competition, change expected for a buy-out competition, and a percent change expected when reverting from previously competitive to noncompetitive procurement. Each option had a unique combination of these step functions.

The initial low rate upward adjustment was made to projected costs from the learning curve. The following factors applied:

Percent Increase

Production	1st year	2nd year	3d year
6,000/mo	30.3	20.2	23.5
3,000/mo	18.7	9.5	12.4

These factors reflected increased unit costs because the automated lines were not operating at design capacity.

Cost improvement associated with split competition was estimated at 7.5 percent for TDP options and 10 percent for FOD options. These rates were judgment estimates based on the APRO 79 study of 22 systems and the consulting report by Putnam, Hayes and Bartlett discussed in chapter 3.

The cost improvement associated with a buy-out was chosen as 15 percent for TDP options and 20 percent for FOD options. This judgement was based on three sources discussed earlier:

- APRO 78

  -- 16 systems studied: Net Recurring Savings -13% to +51%
  Mean Savings of 13.7%

- Institute of Defense Analysis 79

  -- 31 systems studied: Gross Savings -23% to +64%
  Mean Savings of 36.1%

- APRO Letter, 3 October 80

  -- Specific recommendations for this study:
  Gross Savings: 10% TDP options
  15% Freedom-of-design options

The final step-adjustment was made for the transition from a competitive situation back to a noncompetitive situation after the buy-out. A figure of +5 percent was estimated to reflect this decreased competitive pressure.

The basis for recurring cost calculation is the applicable first-unit cost and 91 percent learning curve multiplied by the option's unique step functions. Figures 4-1 and 4-2 depict these step functions over time as they affect each baseline unit cost estimate.[17]

The LRP baseline on the figures represents the low-rate production cost baseline for sole-source production, and the balance of the figures graphically illustrate the impact on the baseline price of the four step functions.

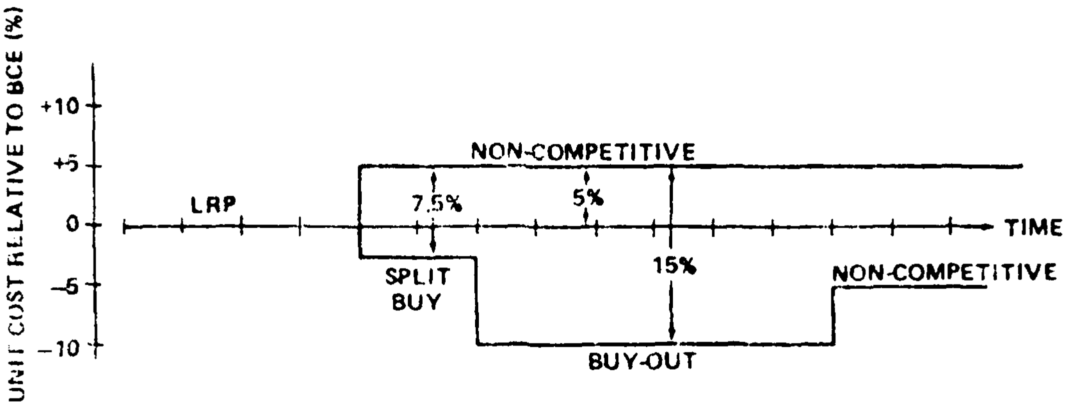

Figure 4-1. Assumed Effects of Competition on Unit Cost (TDP Copy)

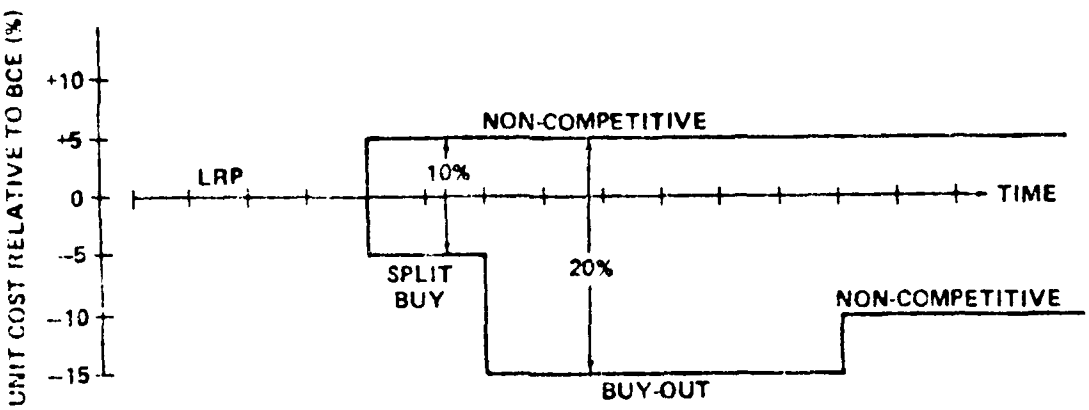

Figure 4-2. Assumed Effects of Competition on Unit Cost (Freedom of Design)

The study derived other cost elements by applying historical factors, developed by MICOM from previous program histories, against the baseline cost estimate for hardware manufacturing cost.

The analysis is calculated in FY 80, then-year, and constant dollars discounted at 10 percent in accordance with OMB Circular A-94 procedures. After evaluating the options, the study concluded there was no single acquisition strategy that was dominant on every issue. Using the calculation in FY 80 dollars, it concluded that 15 of the 40 competitive options were more favorable than sole source.[18] The most favorable option for a total quantity of 190,000 rockets was the

sole-source option at 6,000 per month and the leader/follower rate of 6,000 rockets per month for a total quantity of 360,000 was the most economical. Based on program and contractual issues together with the technical and operational issues, the study recommended a TDP traditional strategy.

Analysis in FY 80 dollars discounted at 10 percent showed that only two of the 40 combinations of options and production rates had potential savings at the total cost level. Both were at a total production of 360,000 using the TDP leader/follower method at a rate of either 3,000 or 6,000 per month.[19]

The team developed a probability distribution of competitive savings to account for the economic uncertainty of the cost estimates. It accomplished this by subjectively assigning probabilities that the cost of a specific option would be less than or equal to the sole-source cost. The distributions also favored the TP leader/follower approach as having the greatest probability of savings.

The study recommended that a total quantity of 360,000 rockets be procured at the rate of 6,000 per month using a TDP traditional approach based on factors other than cost.

Bradley

The Bradley fighting vehicle system (FVS) is a mechanized infantry combat vehicle developed by the FMC Corporation starting in 1977. As of November 1982 FMC had received three production awards totaling 1,700 vehicles out of a proposed total baseline quantity of 6,882 vehicles to be procured through FY 89.

A 1982 study reassessed the costs and benefit of competitive strategies designed to reduce rapidly escalating program costs.[20] The reassessment examined four prior studies of the cost effectiveness of competing the FVS.

It compared the sole-source costs of two competitive strategies. One strategy involved split awards for the duration of the program. The other was a buy-out where a "winner-take-all" competition is held after two years of split awards.

Competition would be based on a technical data package and would encompass the manufacturing and assembly of the vehicle, which represents 45 percent of unit cost. The engine, turret drive, transmission, fire control, and other weapons would be government-furnished equipment. Analysis of the competitive options included examining nonrecurring and recurring costs as well as noncost issues.

Nonrecurring costs were divided into start-up costs and an initial production penalty cost. Start-up costs included additional vendor

tooling, machinery, facilities, training, and engineering costs and were taken from firm-fixed price contractor submission or second-source budgetary estimates. Start-up costs for a second-source production capability of 50 per month were estimated to cost $32.20 million in December 80 dollars. An increase to 90 percent per month would require an additional $10.85 million. The initial production penalty cost estimate ranged from 43.7 to 45.5 million dollars, depending on the strategy. It represents an amount calculated by subtracting the expected FMC price to produce the 234 vehicles in FY 83 and FY 84 and start-up capacity costs from estimated second-source prices for the 234 vehicle education buy in FY 83 and FY 84.

Recurring costs included contract hardware prices, government administrative costs, and other program costs and spillover effects. Contract prices included all contractor costs since a single contract was being contemplated. They were calculated using a quantitative model based on unit learning curve theory of the formulation:

$$C_i = \alpha_i \rho_i \sum_{q=q_{i-1}+1}^{q_i} a q^{(b-\sigma_i)}$$

Where

C_i = total recurring cost through ith item

a = first-unit cost

b = rate of cost improvement

α_i = discount factor for year i

q_i = production experience factor at end of year i

ρ_i = percent reduction in unit cost at year i due to competition

σ_i = relative change in price performance improvement rate at year i due to competition

This formulation can accommodate a potential shift in the learning curve or an improvement in the learning rate (learning curve rotation). It can also be adjusted for production rate and accounts for the time value of money by discounting future dollars. Any one or all the adjustments can be made for any given production year.

Estimates of future year impacts are shrouded with uncertainty. Therefore, the analysis accounted for uncertainty through the use of an event-oriented Monte Carlo simulation. Individual values for each

factor were given minimum, maximum, and most likely magnitudes based on the analysts' judgement. By treating each factor in this manner, the analysts developed a cumulative probability distribution for each strategy.

The sole-source learning curve slope was estimated to follow a 93 percent slope under all competitive conditions for units 1100-6882, consistent with the baseline cost estimate. However, evidence from other vehicle programs revealed a 95 percent slope, and analyses were run using both slopes. The analysts did not expect a rotation of the learning curve as a result of competition, but they did expect competitive pressures to shift the learning curve and the production rate to impact each strategy as follows:

Strategy	Competitive Reduction	Production Rate Penalty	Overall Shift	Range
Multiyear Buy-out	15	0	15	± 10
Multiyear Split-buy	10	-3	7	± 7
Single Year Split-buy	8	-3	5	± 7

The analysts estimated government program office administrative costs to increase $2 million per year and additional testing to cost at .5 million per year for three years. Effects on logistics, maintenance, and engineering sectors were considered minimal and no additional contract administration was deemed necessary. Spillover effects on other government programs were considered and dismissed as balanced out between contractors. Other costs discussed and quantitatively dismissed included contractor systems technical support, contractor data requirements, government furnished equipment, product improvements, and the impact on spares procurement.

The data shown in table 4-6 are the result of inputting the recurring cost values for the parameters into the computer model of price behavior for a production rate of 1,080 vehicles per year and then combining the results with nonrecurring costs for all strategies.[21]

The analysis concluded that the competitive strategies will never show significant savings in discounted dollars. For the dual-source multiyear strategy on a 93 percent curve, expected <u>increase</u> in outlays was 22.2 million (14.4 million undiscounted FY 81 dollars). For the multiyear buy-out strategy the analysts projected a net savings of $19 million. While the analyses were run assuming a production rate of 1,080 a year, the approved baseline quantities are not currently that large and the analyses showed that competition was not economically feasible at the lower quantity using any strategy.

A multiyear strategy was also calculated using cancellation ceilings. Model input factors included:[22]

Table 4-6
Summary of Strategy Savings (Loss) and Savings Probability

Strategy	FY 81 Dollars (Millions)				FY 81 Discounted Dollars (Millions)			
	IA (93%)		IB (95%)		IA (93%)		IB (95%)	
	Delta	Prob.	Delta	Prob.	Delta	Prob.	Delta	Prob.
2A - Dual-Source Multiyear	(14.4)	.35	16.0	.63	(22.2)	.26	(.2)	.50
2B - Dual-Source Single Year	(41.1)	.18	(11.3)	.42	(42.5)	.10	(20.4)	.28
3A - Buy-Out Multiyear Split	46.4	.86	78.1	.98	19.0	.76	42.4	.97
3B - Buy-Out Single-Year Split	32.9	.81	64.4	.95	7.9	.61	31.1	.87

Expanded Multi-Year Input Values

Contract Situation	Reduction	Production Rate	Shift	Range
Sole-Source	7%	0%	7%	± 3%
Competitive Buy-Out	19%	0%	19%	± 10%
Competitive Split-Buy	14%	3%	11%	± 7%

Using POM quantities, sole-source savings of $75.9 million dollars ($104.0 million discounted) were projected.

The authors considered noneconomic issues along with potential economic savings. One identified benefit was better cooperation; another was improved contract terms from the sole-source contractor. They identified as negative factors the probable schedule slippage in the second source and the poor condition of the TDP which might cause claims after award. Additionally, the sole source is not providing some drawings and process data because they allege that this is proprietary data. Also no costs are included for testing of the product by the government, and configuration management will be a problem because the design will still be undergoing changes at the time of contract award. And there is a potential one-year slip in delivery reflecting the cumulative effect of these problems.

The authors' recommended strategy was a sole-source, multi-year award. They noted that this also has the least program risk but leaves the developing contractor in a favorable position. Accordingly, they recommended a "red team" contract to a consultant who will monitor the incumbent's progress and recommend cost-reduction opportunities.

HARM

The high-speed antiradiation missile (HARM) was developed by Texas Instruments, with the warhead consisting of 2,500 preformed fragments. It can be fired in three different modes: self-protection, target of opportunity, and standoff modes. Total procurement was expected to involve 21,388 missiles between FY 81 and FY 92.

The controversy surrounding the decision not to second-source the HARM highlights the inexact nature of estimating the impact of competition. Within the Navy, two separate estimates were accomplished, one by the Naval Material Command (NAVMAT) and one by Naval Air Systems Command (NAVAIR). Both were developed in FY 82 dollars and done because agreement could not be reached on methodology and assumptions.[23] Additionally, OSD Program Analysis and Evaluation (PA&E) acting in its Cost Analysis Improvement Group (CAIG) role, completed a review of the Navy analysis.

Estimates within the Navy were developed individually for three elements: (1) guidance, control, wings, and fins (GC&A); (2) integration and assembly (I&A); and (3) program management systems engineering (PMSE). NAVMAT's estimate was accomplished at the detail level, estimating labor, material, and profit for each of these elements based on the HARM Cost Study Group estimates for sole-source procurement. Competitive impacts were calculated based on Sparrow AIM-7F experience. The NAVAIR developed estimate for sole-source cost was also a detailed estimate developed by the HARM Cost Team. Their competition estimate was done, however, at the bottom line price. Estimates at the bottom line for unit cost for both are shown in table 4-7.

Table 4-7
NAVMAT and NAVAIR
Estimates of HARM Costs
FY-82 ($000's)

NAVMAT Unit Costs

	Sole-Source	Competition Prime	Competition Second	Competition Total
Quantity	21,392	13,860	7,532	21,392
GC&A	132.0	134.9	161.4	144.2
I&A	12.1	12.4	15.0	13.3
PMSE	10.9	13.5	8.2	11.7
Total	155.0	160.8	184.6	169.2

NAVAIR Unit Costs

	Sole-Source	Competition Prime	Competition Second	Competition Total
Quantity	21,392	11,082	10,309	21,391
GC&A	130.6			
I&A	12.2			
PMSE	10.0			
Total	152.8	162.2	134.3	148.8

While NAVAIR showed a net savings, NAVMAT showed an increase of the competitive price over the sole-source price. The sole-source estimates are very close to each other. The principle difference is reflected in the cost of the second source. The official NAVY position at DSARC was that there would be a net savings resulting from second-sourcing.

OSD CAIG reviews of the HARM program, using different methodologies, arrived at different conclusions about the benefits of second sourcing. Disagreements surfaced about learning curve slopes, special test equipment, facilities, and other contractor investments. Additionally, reviewers could not identify which cost elements would be reduced and no contractual guarantees could be obtained to fix the price of the out-year requirements. Accordingly, the secretary of defense directed that the program be procured sole source.[24]

Discussion

Analysis of the program specific estimates of the impact of competition reveals the use of disparate approaches to accomplish the estimates. The studies differ in several aspects: a) cost elements considered, b) depth of analysis of each element, c) whether point estimates or ranges are used to account for uncertainty, d) whether cash flows are discounted, and e) the extent the studies relied on less than robust historical studies. Because of these differences, the confidence that can be placed in their conclusions also varies.

Factors Considered

Chapter 2 identified factors as being quantifiable and nonquantifiable. Quantifiable factors include nonrecurring and recurring costs, profit, and other quantifiable costs. Nonquantifiable factors include cooperation, claims, product quality, time delays, and surge capability. Table 4-8 is a matrix that identifies each program and the factors considered in each analysis. Most of the potential impacts were treated in the studies with two notable exceptions. Excluded were those government costs incurred to select and monitor the second source and those costs and benefits that would impact on other stages of the acquisition process.

The incremental costs directly incurred by the government to select and monitor the second source were the most frequently omitted factors. Specifically, the second-source selection costs were not considered in any analysis except the MLRS study. Moreover, the government costs to monitor and assist technology transfer during second-source development and the additional contract administration costs during contract performance were not considered in any case except those of the Bradley and MLRS analyses. Additionally, these two studies were the only ones that addressed the added cost of configuration management necessary to ensure that the second source receives any change made to production drawings or processes by the developing contractor.

The other quantifiable factors most frequently omitted were those that would be incurred in stages of the acquisition process other than the production stage under immediate consideration. For example, the MLRS analysis was the only analysis considering the impact on company-funded R&D during the concept definition and validation stages. And the Bradley analysis was the only one considering logistics impacts on the system under consideration and the overhead absorption impact on other contracts within the profit center affected by the reduced allocation base. Finally, none of the analyses considered benefits accruing to the government during weapon system deployment. Specifications and drawings owned by the government would allow the government to obtain the benefits of competition during spare parts procurements in the operations and support phase of system deployment.

Table 4-3
Elements Considered by Program Analyses

	MLRS	BFV	AMRAAM	IIR MAVERICK	LANTIRN
Quantifiable					
Nonrecurring					
Second-Source Selection	Y	N	N	N	N
Second-Source Development					
Technical Data Pkg					
Purchase	Y	Y	Y	Y	Y
Validation	Y	Y	Y	Y	Y
Special Tooling	Y	Y	Y	Y	Y
Special Test Equip	Y	Y	Y	Y	Y
Tech Transfer					
Leader-Follower	Y	N/A	Y	Y	Y
Education Buys	Y	Y	Y	Y	Y
Govt Monitoring	Y	Y	N	N	N
First Article	Y	Y	Y	Y	Y
Contingent Liabilities	Y	N/A	N	N	N
Recurring					
Cost/Quantity Relationship					
Production Rate	Y	Y	Y	N	Y
Learning	Y	Y	Y	Y	Y
Contract Administration	Y	Y	N	N	N
Configuration Mgt	Y	Y	N	N	Y
Other Costs					
Company-Funded R&D	Y	Y	N	N	N
Spare Parts	N	Y	N	N	N
Overhead Impact	N	Y	N	N	N
Logistics	N	Y	N	N	Y
Profit	Y	Y	N	N	N
Nonquantifiable					
Productivity					
Product Quality	Y	Y	Y	N	Y
Cooperation					
Technical Transfer	Y	Y	Y	N	N
Ongoing	Y	Y	N	N	N
Time Delays	Y	Y	N	N	Y
Claims	Y	Y	N	N	N
Statistical					
Inflation Adjust	Y	Y	Y	Y	Y
Discounting	Y	Y	N	N	N

N=NO Y=YES

The potential nonquantitative costs and benefits were not considered except in the Bradley and MLRS analyses. Excluding these impacts from analyses removes them from explicit recognition by the decision maker in judging whether the total quantitative and qualitative benefits outweigh potential costs of second-sourcing.

Depth of Analysis

Each estimate varied in the depth of the analysis of identified factors: either the estimating was done at the total contract level for each factor or the factors were disaggregated into individual cost elements. Moreover, some of the studies identified more detailed cost elements than others, some projected cost impacts for the various strategies of technology transfer, while others made estimates independent of the method of technology transfer. The more specific the cost elements are the more confidence that can be placed in their estimation because the impact of competition can be more readily identified. For example, if price is disaggregated into material, labor, and profit, the impact of competition on each of these cost elements is more easily projected than on a total contract price basis. It is also more easily projected when the alternative acquisition strategies are examined separately. The Joint Tactical Information Distribution System (JTIDS) estimate was done at the contract level using a 10 percent rule-of-thumb reduction from the estimated sole-source cost and did not consider differences in the method of technology transfer. The AMRAAM analysts' estimate for recurring costs was disaggregated into four cost elements--material, direct manufacturing labor, manufacturing support, and engineering support labor--and they considered both the sole source and the leader/follower acquisition strategy in their estimates. The IIR Maverick program was disaggregated into the guidance and control section, center aft section, system engineering and program management, sustaining engineering and factory support, engineering change orders, support equipment, and spare parts. The analysts considered three scenarios in their analysis. However, for cost reductions attributable to competition, they took an overall 9 percent cost reduction and 5 percent fee reduction. The LANTIRN estimate was taken at the contract level, and the Bradley and MLRS estimates both estimated the impact of competition on alternative strategies. The MLRS analysis examined four separate acquisition options and estimated the impact for each combination of option and production rate. The Bradley analysis also identified two options and analyzed each independently. Whereas the Bradley analysis was accomplished at the contract hardware price level, the MLRS analysis was done at the detail cost element level.

Point Estimates vs Ranges

Only the Bradley and MLRS analyses attempted to deal with the uncertainty of estimates. Both developed probability distributions to account for the economic uncertainty of cost estimates. The MLRS used a subjectively assigned probability and the Bradley used a Monte Carlo technique to set forth a cumulative probability distribution.

Discounting

The Army estimates were the only analyses discounted in accordance with the requirements of OMB Circular A-94. Consequently, the other analyses tended to understate the true costs to the government because they ignored the time value of money by considering a $1 invested up-front in nonrecurring costs the same as a $1 cost avoided several years into the procurement.

Reliance on Historical Data

Most of the program studies relied on unweighted average savings derived from historical studies. The JTIDS 10 percent rule-of-thumb decrement was based on expert judgement and nonattributive references to prior studies that averaged greater than the 10 percent figure. LANTIRN and Maverick both relied exclusively on The Analytic Sciences Corporation (TASC) studies of historical data. AMRAAM relied on proposal data from the Sparrow and Sidewinder programs because they did not accept the TASC analysis done for them. The MLRS projected the step function adjustment associated with buy-out based on an average of average savings taken from the APRO 78 and IDA 79 studies, and an APRO letter of 30 October 1980. The Bradley analysis projected shifts of learning curves based on a review of historical studies.

Conclusions

It is not possible to directly assess the confidence placed in the predicted cost impact of second-sourcing because what never happened is immeasurable; it is impossible to know what the price would have been in the absence of competition. And the differences of opinion surrounding the HARM analysis serve to highlight the differences of opinion that can develop among competent analysts. However, the robustness of the various studies can be inferred from the review of the five aspects of the studies just covered: factors considered, depth of analysis, use of point estimates or ranges, discounting of cash flows, and the reliance on historical studies' unweighted average data.

Each study satisfied each criterion to a different degree, as discussed earlier. The Bradley and MLRS analyses tended to consider more of the substantive cost factors than did the other studies. The AMRAAM, Maverick, and MLRS each examined multiple strategies separately at the detailed cost level. The Bradley and MLRS were the only two analyses dealing with uncertainty and also discounting program cash flows over time. And finally the AMRAAM study, although relying on proposal rather than actual data, was the only study not relying extensively on the unweighted historical averages data.

No study was able to adequately address all criteria. While the MLRS and Bradley studies were the more comprehensive in projecting the

true impact to the government by considering most of the cost factors and discounting the cash flows, all studies relied on the historical data to more of an extent than the rigor of the historical studies allow, as argued in chapter 3.

Chapter 5 will now propose a framework that can be used in competition analysis that will overcome the methodological and data shortcomings that presently do not allow satisfaction of the criteria.

NOTES

CHAPTER 4

1. DOD Directive 5000.4 OSD Cost Analysis Improvement Group, 30 October 1980.

2. IIR Maverick Independent Cost Analysis (Wright-Patterson AFB, Ohio: Directorate of Cost Analysis, Comptroller, Aeronautical Systems Division, February 1983).

3. Ibid., 92.

4. Ibid., 126.

5. Ibid., 12.

6. Phillip H. Ambs, Competitive Procurement Plan Update for Lantirn, Rpt TR-4611-6 draft (Reading, Mass.: The Analytic Sciences Corporation, 1 May 1983).

7. Ibid., 2-23.

8. Ibid., 3-3.

9. Letter, subj: "Review of Lantirn Leader/Follower Projected Cost Savings," signed William W. Yoder, Deputy Director, Cost Analysis, Comptroller, HQ Aeronautical Systems Command, Wright-Patterson AFB, Ohio, 8 August 1983.

10. "Understanding the Competitive Procurement Environment", study (Eglin AFB, Fla.: Cost Analysis Division, Comptroller, Armament Division, undated).

11. Analysis of AMRAAM Acquisition Alternatives, Phase II, Final Briefing Rpt SP-4049-3 (Arlington, Va.: The Analytic Sciences Corporation, 1 March 1982).

12. Ibid., 70.

13. In a letter dated 24 July 1984 commenting on this study, Armament Division stated that in the "AMRAAM ICA report and the AMRAAM ICA presentations for DSARC II, both 'net value' and 'internal rate of return' calculations were prepared and presented."

14. "MLRS Second Source Rocket Acquisition Study" (Redstone Arsenal, Ala: US Army Missile Command, December 1980).

15. Ibid., 75.

16. First unit cost for a "crated rocket," a construct created to facilitate comparisons between options. Further detail is at page B-1.

17. Ibid., B-7.

18. Ibid., 72.

19. Ibid., 74.

20. "IFV/CFV Second Source Reassessment Report" (Ft Lee, Va.: US Army Material Development and Readiness Command, Army Procurement Research Office, 30 April 1982) (For Official Use Only).

21. Ibid., 47.

22. Ibid., 58.

23. John Dorsett, "High Speed Anti-Radiation Missile (HARM) Cost Estimate Summary", Naval Material Command, Cost Analysis Division, (Washington, D. C.: July 1982).

24. Classified decision memo, 30 April 83, signed by Secretary of Defense Weinberger.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The decision to second-source a weapon system in its production phase should be made as early in the acquisition process as possible to allow maximum flexibility for choice of the method of technology transfer to the second source. And the decision to second-source must be made in consonance with the primary acquisition program objectives: system technical performance, production surge capability, required delivery schedule, life-cycle system cost, and system supportability. Each possible strategy (such as leader/follower or freedom-of-design approach) affects the objectives in different ways.

Several studies have looked at acquisition strategies. Duane Knittle and Robert Williams coauthored a paper examining the systems acquisition planning phase used to plan the strategy for achieving program objectives for the entire life of an acquisition.[1] More recently Charles Smith and Charles Lowe, Jr., coauthored a paper on strategy selection for the production phase of the acquisition cycle.[2] They propose a strategy selection model integrating judgement and existing quantitative data to achieve stated program objectives. They first use a competition screen to qualitatively screen out programs not susceptible to competition because of unavailability of technical data, government inability to monitor technical transfer, and other criteria. Their second step involves a cost model based on the basic learning curve theory where judgement of shifts and rotations are made by program personnel and the results discounted to project savings. And the study points out in referring to historical studies:

> The underlying data are simply too erratic to permit accurate projections of savings. . . . Also each successive study tends to be further removed from the primary data. . . . Another reason to avoid over-generalization blindly from the data base is that the cases studied have had a conglomeration of strategies, but the results have all been lumped together.[3]

Neither study provides a theory of the interaction of variables that are affected by the competitive forces and how these forces affect the price of the various strategies. For this reason, they are not predictive models of savings.

The literature contains several other predictive models, as discussed in chapter 3, that were used in program specific analyses in chapter 4 to address one specific program objective--cost. However, I have argued that they have not empirically demonstrated the validity of their models. Moreover, I believe that there are so many interactive variables that must be considered that no mathematical model can be developed. Even if we could develop a model of the variables,

insufficient data exist to empirically verify its validity. Our track record of estimating what the future cost of a weapon system will be, while improving, still falls far short of acceptability. A quick perusal of any quarterly Selected Acquisition Report too vividly reveals our inability to accurately project future weapon systems prices.

Our inability to accurately forecast future weapons system costs, to accurately specify a model for savings, or to empirically verify a model because of a lack of data--even if a model could be specified--does not relieve acquisition personnel of the requirement to perform competition analyses for decision-making and budgeting purposes. The balance of this chapter sets out a macro model for use in competition analyses. The model assumes that potential second sources are technically qualified and that technical data is available for competition at both the prime and subcontract level. It also assumes that sufficient time exists to develop the second source and that the supportability issues have been examined. These simplifying assumptions narrow the focus of the second-source initiative to that of achieving minimum system cost to execute the legislative and executive branch thrusts discussed in chapter 1. The model does, however, develop a framework that allows the logical examination of the impact of second-sourcing on other program objectives.[4]

Proposed Model

The proposed model for use in competition analyses where competition is undertaken for cost-reduction purposes is a discounted cash-flow investment macro model. Using this concept, the government views the development of the second source as an investment decision where the nonrecurring costs are incurred by the government in anticipation of a reduction in future recurring costs. Previous analyses reviewed in this study used the concept of "savings" as the criterion to measure the cost effectiveness of the investment. To arrive at the measure of savings, most analyses projected what the sole-source price would have been, what the competitive price actually was, and claimed the difference as "savings."

The macro model replaces the criterion of savings with the criterion of judgement as to whether or not the government has a good probability of recouping its investment in nonrecurring costs. The discounted cash flow investment model involves three steps: first, estimating the additional costs to the government because of second-sourcing, including the required nonrecurring costs to qualify the second source and any other additional costs or penalties; second, decreasing the estimated sole-source price by an amount equal to those costs not susceptible to the cost pressures of competition; and third, making an informed judgement of the probability that the government would recover its nonrecurring investment through reduced recurring costs.

In contrast to the studies accomplished to date, which involved formal quantitative methods based on less-than-complete theory and data, the proposed method combines use of data and judgement. It does not involve the reading of tea leaves or a referral to a palm reader. It is a structured analysis that uses logic to iteratively narrow down the breadth of available information and focus in on a smaller information base where judgements can be made on carefully defined issues. The model avoids the drawing of conclusions from unverified data in the absence of an adequate theory, and it avoids the estimating of several parameters from few data points.

The analysis is conducted in discounted present value terms to account not only for the magnitude of the cash flows over time, but also for the timing of the cash flows in terms of both costs and benefits. Each potential strategy can create different patterns of additional up-front costs and downstream benefits. A discounted cash-flow analysis considers these different cash-flow patterns in deciding which strategy is the most advantageous to the government. It is similarly used in multiyear and technology modernization/industrial modernization incentives program analyses where up-front investments are also made in anticipation of downstream benefits.

The internal rate of return and the net discounted present value are two potential methods to measure investment potential. The internal rate of return is the discount rate that makes the present value of the benefits exactly equal to the present value of the costs. Put another way, it is the discount rate that makes the present value of the entire stream of costs and benefits exactly equal to zero. The discounted net present value--discussed in chapter 2--is the sum of the costs and benefits discounted at a specified discount rate. If the sum is a positive number--that is, the discounted benefits exceed the discounted costs--the investment should be made. In general terms, given a stream of cash flows C_0, C_1, C_2, . . . , C_n, where Cs are positive, zero, or negative, the net present discounted value is given by

$$C_0 + \frac{C_1}{(1+r)} + \frac{C_2}{(1+r)^2} + \ldots + \frac{C_n}{(1+r)^n}$$

where r is the discount rate. OMB Circular A-94 specifies that a discount rate of 10 percent be used where the cash flows for government investments exceed 3 years. Therefore, the discounted net present value model is the appropriate criterion for use in second-source decision making.

Nonrecurring Costs

Exercise of the 3-step macro model begins with the relatively straightforward process of estimating the up-front nonrecurring costs. These readily identifiable, near-term costs, which were discussed in

chapter 2, can be incurred by both the government and the contractor. Additionally, other increased costs requiring an estimate include: the learning curve and production rate penalties; the negative impact on other programs within the profit center due to changed overhead allocation bases; and the other impacts discussed in chapter 2, such as reduced contractor investment early in the program because of potentially lower follow-on production contract awards.

Depending on the requirements of the technology transfer method, as discussed in chapter 1, each potential strategy can have different cost profiles, both in magnitude and timing. For example, the technical data package transfer would occur earlier in a teaming arrangement than it might under a leader/follower situation. An education buy might be required under a leader/follower procedure and not required under a teaming arrangement. And learning curve penalties will vary based on the timing of the buys. These would be the negative "Cs" in our discounted cash flow formula and would be identified by the year they would be incurred and the constant dollars discounted to a base year.

Costs Not Susceptible to Competition Benefits

Step two involves estimation of the program costs that are not susceptible to reduction because of the pressures of competition. Included would be material and subcontract purchases already competed by the developer and contracted for on a firm-fixed-price basis. The percentage of total contract expenditures fitting this category can vary significantly between contracts. Table 5-1 illustrates how these figures varied on 12 programs. Competitively purchased material as a percentage of total contract costs ranged from 2.1 percent to 50.2 percent.[5] The study that compiled these data also concluded that 42.94 percent and 78.93 percent of all subcontract dollars were spent competitively by DOD contractors and government-owned, contractor-operated plants, respectively.

Also included in costs not susceptible to competition benefits are those material and subcontract purchases where a potential second source would use the same supplier as the developer for schedule availability, technical capability, or economic production quantity reasons. This also holds true for the following costs:

- When there are fully automated manufacturing processes.

- When there are mature components where no potential learning exists as verified by a fully validated work measurement system.[6]

- When the components are sold in substantial quantities to the general public with an established catalog or market price.[7]

- When the prices are otherwise set by law or regulation.

- When mandatory sources are specified.[8]

Table 5-1
Subcontract Competition in Selected Major System and Large Dollar Programs

SYSTEM/CONTRACTOR	TOTAL CONTRACT COST (TCC)	PURCHASED MATERIAL AS A % OF TCC	PURCHASED MATERIAL: COMPETITIVE PURCHASED MATERIAL AS A % OF OF TCC	PURCHASED MATERIAL: COMPETITIVE PURCHASED MATERIAL AS A % OF PURCHASED MATERIAL
I. ARMY				
AHIP/BELL HELICOPTER	$135.3M	54.4	50.2	92.3
STINGER/GENERAL DYNAMICS	104.0M	54.0	18.0	33.3
FIREFINDER (TPQ-36)/HUGHES[1]	239.5K	36.1	23.4	64.7
FIREFINDER (TYP-37)/HUGHES[1]	154.2K	31.1	13.2	42.6
FVS/FMC	519.4M	75.7	19.6	25.9
M1/GENERAL DYNAMICS[2]	-	68.6	26.4	38.5
PATRIOT/RAYTHEON[3]	242.2M	53.3	2.1	3.9
UH-60/SIKORSKY	611.1M	50.9	41.4	81.4
PERSHING II/MARTIN MARIETTA	594.8M	51.6	12.3	23.8
II. NAVY				
F-14 GRUMMAN	$ 479.0M	53.1	3.5	6.6
CVN-70/NEWPORT NEWS SHIP[4]	1142.0M	25.0	13.0	52.0
III. AIR FORCE				
F-16/GENERAL DYNAMICS	$696.4M	58.4	24.9	42.6
A-10/FAIRCHILD-REPUBLIC	246.2M	42.6	9.5	22.3
			WEIGHTED AVG. =	38.0%

1 FIREFINDER data reflects expected costs.
2 $ not available.
3 Major sub controls 62% of contract material cost of which 19.1% is competitive.
4 Competition data based on sample of purchase orders.

- When there are any other costs that, in the opinion of the program manager, are not susceptible to cost reduction through the direct pressures of competition.

Finally, allocations for independent research and development, and facilities capital cost of money should be identified as being in the long-term best interests of the government and tallied as not being susceptible to reduction through competitive pressures.

Those costs not susceptible to reduction through the pressures of competition, or those costs whose reduction is not in the best long-term interests of the government would be subtracted from the estimated sole-source price in the year they would be incurred, leaving a projected dollar figure for each year of an amount susceptible to the pressures of competition. These constant dollar figures would be discounted to the base year.

Judgement Factors

Step 3 involves calculating the percentage reduction, in net present value terms, that total costs susceptible to competition would have to be reduced to recover the up-front investment costs and added costs to this and other programs. This is accomplished by dividing the sum of estimated nonrecurring and other costs by the recurring costs susceptible to the pressures of competition. An informed judgement could then be made by the program manager of the probability that the recurring costs susceptible to competition pressures could be sufficiently reduced to recover the investment costs and penalties. Both figures would be expressed in constant dollars discounted at 10 percent in accordance with OMB circular A-94. Factors to consider in establishing the subjective probability include contractor-related issues and program-specific characteristics.

Contractor-Related Issues. Traditional microeconomic theory assumes firms want to maximize profits. However, others have argued differently. William J. Baumol believes that large firms attempt to maximize sales rather than profits.[9] And Richard Cyert and James March posit that firms simply attempt to "satisfice"--reach some satisfactory level of multiple goal accomplishment: profit, sales, market share, production and inventory.[10] Peter Drucker also comments on corporate objectives and states that the long-run objective is survival and that to emphasize only profit misdirects managers to where they may endanger the survival of the business.

The Army Procurement Research Office conducted a 1981 study on government contractor motivation.[11] Its research concluded that industry felt its objectives were, in order of priority, to provide a good product, to maintain a long-term continuing government relationship, to improve cash-flow, to make a profit, to develop new capabilities, to maintain a positive public image, and to use excess capacity. And, as could be expected, this list varied by both firm

size and growth status, manufacturing process used, and the type of industry. One of the major conclusions was that the government must understand contractor motivation in order to give proper incentives for contractor performance.[12]

Others have written about what might happen when split awards are made during production competition. Brent Meeker, writing in Program Manager, argues that any scheme that does not provide for zero allocation can engender reverse competition, a situation where both companies decide that the smaller quantity is sufficient, bidding higher prices accordingly.[13]

The major point of these discussions and examples is that the contractor might have objectives other than profit maximization. These can include use of idle capacity or the development of new technology. The program manager must be sensitive to these motivations in his subjective probability assessment of how much the developing contractor can and will cut prices.

Program-Specific Characteristics. Several program characteristics should be considered by the program manger. These include the total quantity subject to competition, maturity of the product design, estimates of the efficiency of the developer, amount of touch labor, and the amount and type of subcontracting.

The total quantity subject to competition, including foreign military sales and other systems using identical components or production processes and facilities, affects the opportunity to recoup nonrecurring costs. Generally, the larger the production quantity and the longer the manufacturing horizon of this production quantity, the greater the chance the pressures of competition can exert their downward price pressures. This results because the contractors have more opportunity to efficiently plan their production processes. Moreover, additional incentives to invest in efficient equipment might occur if it helps achieve their corporate objectives.

The maturity of the product design affects the number of engineering changes that might occur during weapon system production. This in part determines the ability of the contractor to reduce the quantity of systems engineering and program management costs charged to the program, usually a level-of-effort charge partially dependent on the maturity of the system. It is also a factor in determining the magnitude of interface charges the developing contractor will have with the second contractor. Additionally, it will determine the incremental configuration management costs necessary to keep the technical data package updated.

Subjective evaluations of the efficiency of the contractor and the quantity of touch labor and type of jobs they perform will help in judging the probability of cost reduction. Particularly useful is an evaluation of the contractor's use of a work measurement system--such as MIL-STD-1567. Additionally, the use of the MIL-Q-9858A quality system

reports on the costs of quality, scrap, and rework are enlightening on the efficiency of production methods.[14]

The amount and type of subcontracting is related to the complexity of the product. If the complexity of subcontracts is high, or there is only one supplier or subcontractor for much of the required materiel, the chances for price reduction are reduced. The state of the contractor's purchasing system as revealed in the government's "contractor procurement system review" is a good gauge of contractor attempts to stimulate subcontract competition. Additionally, a review of the program specific make-or-buy plan would also give insight into the potential for price reduction.

Taken together, consideration of these areas that affect the potential for competitive cost reduction--company and program-specific factors--will help the program manager determine the probability of recouping the investment in nonrecurring costs. In many ways this logical thought process is similar to a "should cost" study. And even if it is judged by the program manager that the costs cannot be recovered, the information derived from the analysis puts the contract negotiator in a position to negotiate better prices in the sole-source situation.

Stylized Example

A stylized example can serve to illustrate the exercise of the model. All dollar figures are discounted present value.

Given:

N_C = nonrecurring cost = \$200

Q = total quantity = 50

P = projected sole source price = \$1500

R = rate and learning curve penalty = \$250

C = projected costs not susceptible = \$100

Step 1

Added costs = $N_C + R$

\$200 + \$250 = \$450

Step 2

Costs susceptible to competitive pressures = P - C

\$1,500 - \$100 = \$1,400

Step 3

Needed percentage reduction =

Added costs $\div$ costs susceptible to competitive pressures = \$450 $\div$ \$1,400 = .32 x 100 = 32 percent

In the example, recurring costs susceptible to competition would have to be reduced 32 percent to recoup the investment and other added costs. If that required percentage were higher--say 50 percent--it would be less likely that recurring costs could be reduced by that amount. In either case, the program manager must make a decision on the probability that costs susceptible to the pressures of competition can be reduced by the derived percentage figure.

Sensitivity Analysis

Having used the proposed framework in a logical manner to draw reasoned conclusions, analysts should conduct a sensitivity analysis to determine what the impact of changes in key factors is on the conclusions. It serves as a "what if" exercise and provides additional information to the decision maker about the impact of uncertainty on his judgmental decision.

Factors to consider include firmness of the estimated quantity, changes in the inflation rate, certainty of estimates of the nonrecurring costs, changes in the timing of the buys, or changes in the timing the second source becomes a viable suppler. Reduced quantities would dictate that the percent reduction of the sole-source price on remaining quantities would have to be higher to recoup nonrecurring costs. Slipping production quantities into future years would reduce the present value of the out-year benefits. Delaying the tooling of the second source would reduce the present value of the nonrecurring costs.

Each change in the calculation that affects either the timing of the investment or the timing of the returns affects the price change needed to recoup the investment cost. And the proposed macro model pertains only to the program objective of cost control. But the program objectives are interactive. For example, delaying the development of the second source reduces the cost of the program in discounted dollars. However, this action also affects the availability of the weapon system. And if the original production schedule is maintained, bringing the second source on-line later, the opportunity to recoup the nonrecurring costs is decreased because of the reduced quantity subject to competition. The analysis, while developed to focus on the cost objective, provides a focus on the trade-offs between program objectives. Other benefits that could come from the analysis would be a more informed judgement on the costs of an enhanced surge capability.

Recommendations

Two recommendations are made to Headquarters AFSC:

(1) Require competition analyses based on an investment recoupment model in lieu of a projected savings model based on historical data.

(2) Require competition analyses in discounted dollars in accordance with OMB Circular A-94.

Recommendation One

This recommendation is made to encourage analysts to move away from the concept of projecting savings because of the problems of methodology and data discussed in this report. It is also made because of a concern that budget decrements could occur through a directive to compete a system based on the faulty assumption that a specified percentage savings will result through competition. Three actions will institutionalize this recommendation.

First, Air Force regulations dictate guidelines in this area. AFSC/AC should initiate recommendations to modify the following Air Force regulation and pamphlet:

AFR 178-1, paragraph 1-1h. Require that economic analysis within the meaning of the regulation be accomplished for major weapons systems procurements on the costs and benefits of competition in production. The regulation should require that explicit recognition be given to all costs and benefits to the government as discussed in this study, taking a life-cycle perspective of the given program.[15]

AFP 178-8, Section B. Incorporate a sample economic analysis in the document using the framework for second-source production competition analysis set out in this study.[16]

Second, training courses for program control and cost analysis personnel should incorporate materials on this subject in their curricula to clarify the shortcomings of existing studies and present a reasoned alternative. Additionally, the Defense Systems Management College is preparing a proposed DOD Competition Handbook which discusses previous shortcomings, proposes discounting, and also has a caution about the use of historical data. When printed, distribution should be made to AFSC personnel.

Third, top-level DOD personnel must avoid references to average savings in their speeches, articles, or testimony before the Congress, so that they do not perpetuate the faulty conclusions about average savings.

Recommendation Two

The second recommendation originates because of the time value of money. Again, an Air Force regulation mandates procedures. AFSC/AC should inititate a recommendation to change AFR 173-11, paragraph 7J, to require discounting of cash flows for ICA estimates of the impact of competition in production.[17]

Additionally, AFSCR 173-9, table 3, rule 2, should be changed to include the following questions:[18]

Are--
Production competition cash-flow estimates discounted?

Were--
Rules-of-thumb or unweighted average savings estimates for the impact of production competition avoided?

Closing Thoughts

Competition and the free enterprise system have helped give this country the highest standard of living known to man. However, in many instances the competitive forces of the market place are absent in the defense market for major weapons systems; there exists only one buyer, and the barriers to entry into the market preclude many firms from entering. These barriers include both the high cost of investment and the lack of availability of technology. Developing a second source at government expense is one option to stimulate competition. However, as seen in the subcontract example, not all dollars placed "noncompetitively" at the prime contractor level are spent noncompetitively.

There are other options to reduce the high cost of weapons systems--breakout, multiyear procurement, technology modernization/industrial modernization incentive program (IMIP), and increased subcontract competition. The use of these mechanisms to achieve cost avoidances should also be explored. They can affect program cost without the necessary investment in duplicate tooling. And in the case of the IMIP program the benefits of automated production can be reaped on several programs by tooling up the system developer after down-selecting at the beginning of full-scale engineering development.

Second-sourcing in production is a viable tool for cost reduction, but neither a total virtue nor original sin. It is a tool to be used to achieve specific objectives. It will not always save money as some have intimated. Given the appropriate conditions, it can save money if the recurring cost reductions exceed the nonrecurring costs. The methodology proposed in this report can help make this decision by elevating to a visible level critical information necessary to make appropriate judgements. And even if it is determined that it is not economically feasible to stimulate competition, the program manager is armed with information to have his staff better prepared to negotiate sole-source contracts.

NOTES

CHAPTER 5

1. Duane Knittle and Robert Williams, "Acquisition Strategy Development," Rpt APRO-904 (Ft Lee, Va.: US Army Procurement Research Office, February 1981).

2. Charles Smith and Charles Lowe, Jr., "Strategy Selection for the Production Phase of Weapon System Acquisition" (Ft Lee, Va.: US Army Procurement Research Office, May 1982).

3. Ibid., 22, 29.

4. The impact of second-sourcing on the other program objectives varies with the type of technology transfer method chosen. The methods adequately covered in the literature.

5. Wayne V. Zabel and Charles A. Correia, "Subcontract Competition," Rpt 82-11 (Ft Lee, Va.: Army Procurement Research Office, November 1982), 13.

6. In accordance with MIL-STD-1567, "Work Measurement Systems."

7. These are similar criteria to those specified in P. L. 87-653, Truth in Negotiations Act, 10 USC 2306 (f).

8. As when the contractor must order jewel bearings from the William Langer Plant in North Dakota under the provisions of DAR 7-104.37.

9. William J. Baumol, Economic Theory and Operations Analysis, 3d ed. (Englewood Cliffs, N. J.: Prentice-Hall, 1972), 320.

10. Richard M. Cyert and James G. March, A Behavioral Theory of the Firm (Englewood Cliffs, N. J.: Prentice-Hall, 1963).

11. Robert F. Williams and Daniel M. Carr, "Contractor Motivation Theory and Applications" Rpt 80-06 (Ft Lee, Va.: Army Procurement Research Office, March 1981).

12. Ibid., 61.

13. Brent Meeker, "Second-Source Splits: An Optimum Non-Solution," Program Manager, 13 (March-April 1984): 5.

14. Military Specification MIL-Q-9858A, "Quality Program Requirements," paragraph 3.6, requires contractors subject to its provisions to monitor and take corrective actions where the costs of scrap and rework are excessive.

15. Air Force Systems Command Regulation 173-9, "Cost Estimate Documentation," 11 March 1982, 3.

16. Department of the Air Force Regulation 178-1, "Economic Analysis and Program Evaluation for Resource Management," 14 December 1979, 1-1.

17. Department of the Air Force Regulation 173-11, "Independent Cost Analysis Program," 12 December 1980, 3.

18. Department of the Air Force Pamphlet 178-8, "Economic Analysis Procedures Handbook," 19 May 1981, 1-1.

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